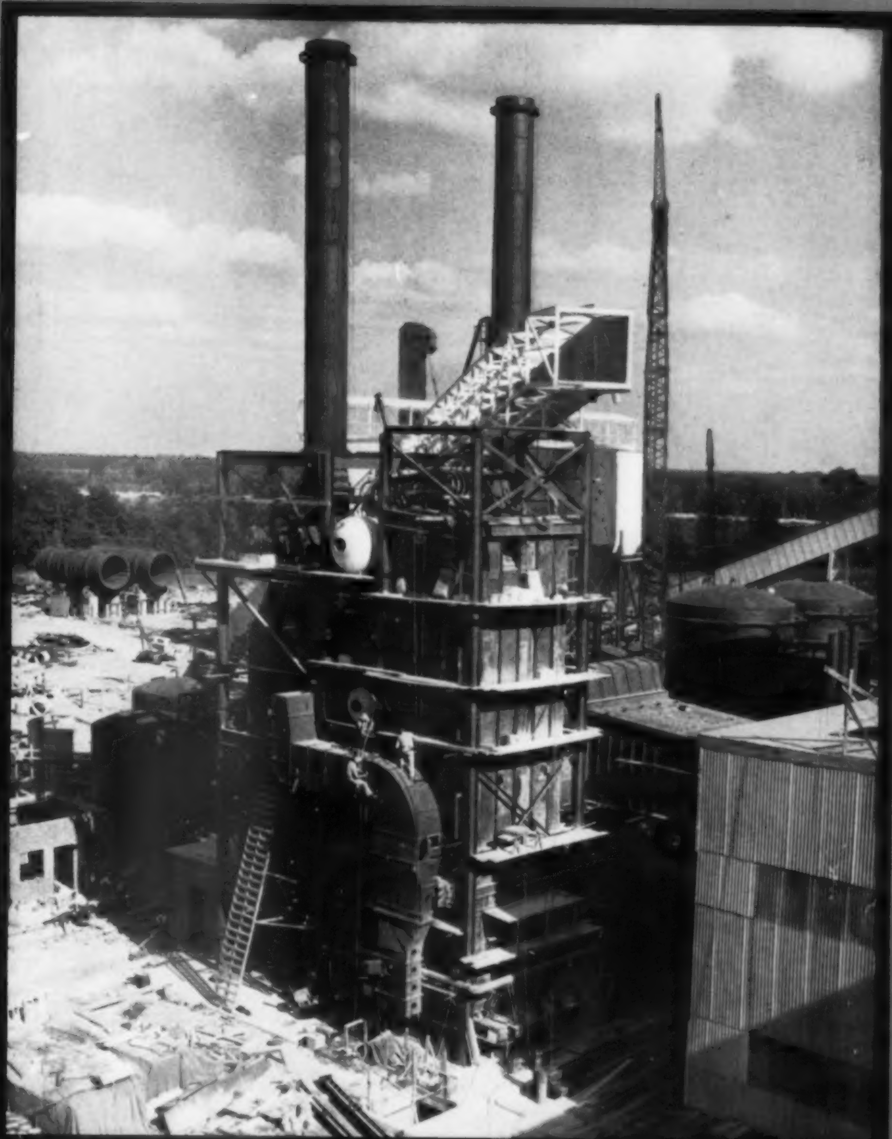
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

June 1954



Construction View showing bark and power boilers at Valdosta, Georgia, plant of National Container Corporation

First Central Station Nuclear Power Plant

Steam Purity Determination—Part III

Accuracy of a Mechanical Coal Sampler

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Feature Articles

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Editorials

How to Interest Youth in Mathematics

The current (May 1954) issue of the *American Engineer*, published by the National Society of Professional Engineers, carries one of the hardest hitting challenges to engineers to take a more active role in shaping and educating youth that we have ever seen. This challenge appears in the article "Have We Lost Control of Our Profession?" by Major General S. D. Sturgis, Jr., Chief, Corps of Engineers, U. S. Army.

We quote: "One insidious influence on both the quality and quantity of engineers, the full impact of which is scarcely yet being felt, is the general drift in public schools away from mathematics and science towards the so-called social studies. The mental discipline of the three R's has been thrown overboard in favor of 'happy, well-adjusted children.' As you can recall from your own school days, not many children derive joy from pursuing the logic of Euclid, yet the study of mathematics is the foundation of all engineering. And if the foundation is faulty or lacking, what will become of the superstructure? Either we must be prepared to lower our standards to accept the socially-adjusted products of a 'happy' but intellectually-empty, childhood or we must be prepared for a really serious shortage of engineers.

"Let me cite to you a few figures. In the school year 1948–1949, of all the public high school students in the United States, the percentage enrolled was only 15.1 in elementary algebra; 5.4 in intermediate algebra; 8.7 in plane geometry; 1.4 in solid geometry; 1.6 in trigonometry; 5.9 in chemistry; and 4.0 in physics. In a study of 200,000 students, only 6 per cent of the eighth graders examined could find 2.1 per cent of 60. In a test given the freshman class at the University of Michigan, only 66 per cent could multiply $2^1/_2$ by $3^1/_4$ and only 68 per cent could express $^3/_{20}$ as a decimal. They made a slightly better showing in dividing 7642.38 by 1000—81 per cent solved the knotty problem correctly.

"All this is serious enough just on the surface. At the very best, it means lowered standards of engineering education and lowered standards of living. But of far graver consequence is the very real threat that while our fine engineering educational system is being starved to death through lack of adequate raw material, our enemy is making substantial gains in this same field. In spite of all that you may hear about barbaric conditions in Russia today, there is nothing backward about their technological training. From all that we can gather of their engineering schools, their students are fully prepared for advanced work at entrance; their schools are well run; their courses of instruction, although generally similar to ours, are considerably longer and somewhat more rigorous with great emphasis placed upon field work; and their finished product—the graduated engineer—seems to be of excellent quality.

"In an age of technology, our country can ill afford to permit any progressive sapping of her technological vitality at a time when our enemy is making steady engineering advances. I ask you therefore: What active, positive and continuing steps will the engineering profession take to increase the output of properly trained engineers from our American educational system?"

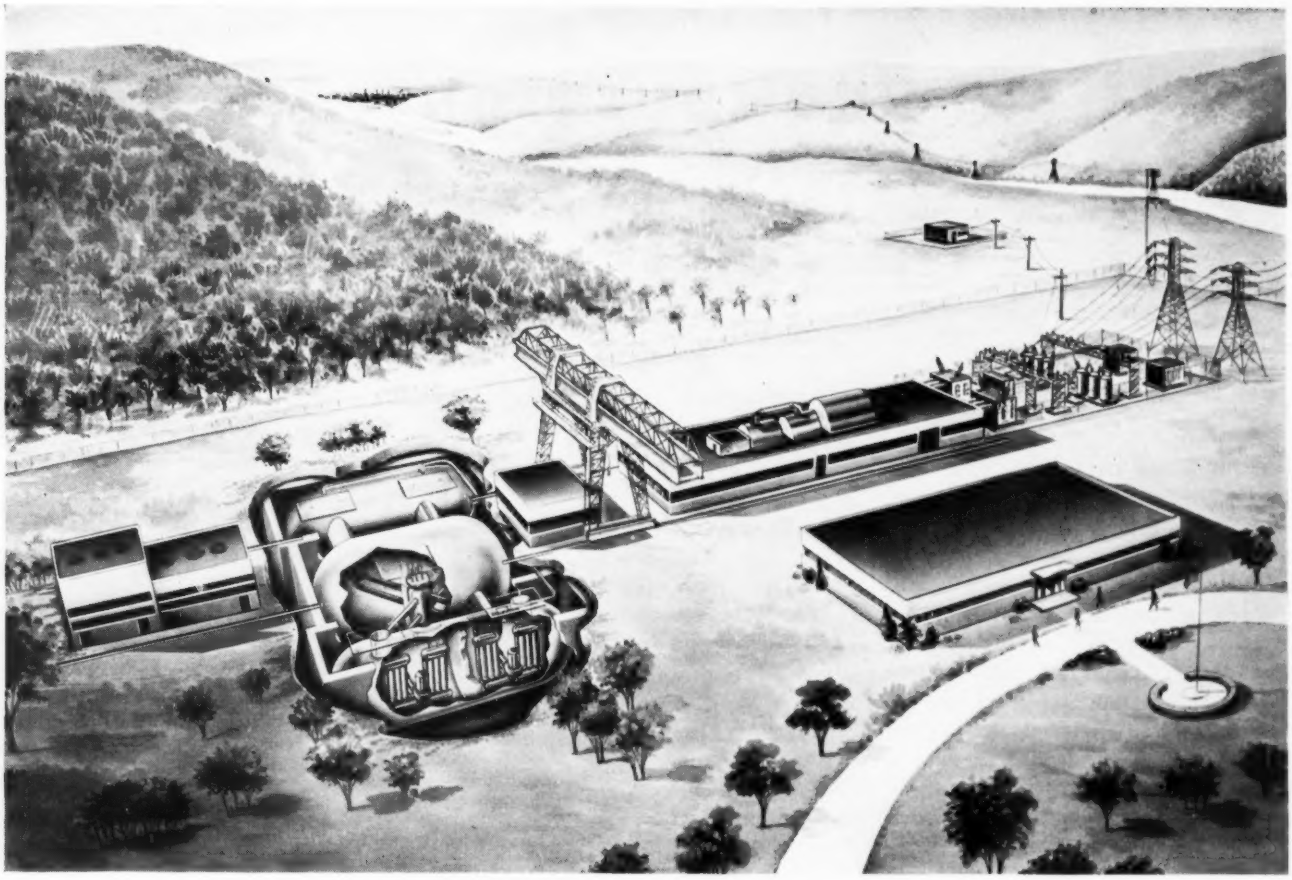
Certainly the above is enough reason to take stock. If our educational balance is as badly wanting as these data indicate we must get the facts across to our local boards of education. Further, we must see that promising youngsters at the grammar school age are guided into the necessary math subjects in high school so that they can build the proper foundation for a later engineering education. Here is a task for all of us at our individual community level.

Leasing Capital Equipment

In several areas of industrial activity, rental of production facilities has become prominent. Machine tool manufacturers have been especially active in promoting use of their products through leasing arrangements. But to the best of our knowledge, leasing has not been the practice in the power plant field except for construction equipment and certain types of air compressors.

Early in May the American Management Association sponsored a special conference in New York on the subject of capital equipment replacement. At one of the sessions, F. J. Muth, assistant controller of Armstrong Cork Co., discussed the merits of leasing versus outright ownership. He pointed out that the trend toward leasing is based upon (1) release of capital for inventories and accounts receivable, (2) assurance of low costs with modern equipment instead of high costs for obsolete productive capacity, and (3) feasibility of acquiring machines needed for short periods. Leasing does not always result in cost savings to the user, and its main appeal may be to those who are short on capital and adopt it as a means of getting into business.

Perhaps the key to leasing as far as steam power plant practice is concerned is that, in general, only standard equipment is rented, and then only if it is subject to re-renting. Whether standardization will ever take place in power plants to the extent that renting becomes widely feasible remains to be seen.



Preliminary artist's sketch of complete plant

Basic Design of First Central Station Nuclear Power Plant

The following is adapted from remarks made before the Forum on Nuclear Reactor Development sponsored by the Atomic Industrial Forum and held in Washington, D. C., on May 24. Some of the basic design considerations for the station to be constructed for the Duquesne Light Company are revealed by the author who is manager of the Westinghouse Atomic Power Division.

By CHARLES H. WEAVER
Westinghouse Electric Corporation

EFFECTIVE July 1, 1953, Westinghouse was assigned responsibility for the development and design of a pressurized light water reactor and primary coolant circuit intended as the heat source for generating civilian electric power. To carry out this responsibility, Westinghouse was authorized to do, or cause to be done, the following: (*a*) such research and development work as is necessary for the design of the reactor and primary coolant circuit; and (*b*) the necessary design and engineering work, including scheduling of the work and preparation of plans and specifications. Westinghouse was also assigned responsibility for the manufacture, fabrication, assembly and testing of the pressurized water reactor.

It was expressly agreed that, at some later date, the Atomic Energy Commission would select a contractor or contractors for the engineering and construction of the steam plant, the electrical generating plant and site facilities; for the procurement and installation of associated components; and for operation of the entire plant complex, including the reactor.

On October 22, 1953, Commissioner Thomas E. Murray formally announced the award of this contract to Westinghouse. In the course of his announcement, he invited industry to propose ways and means whereby it might participate in the project and help defray the cost.

On December 7, 1953, an official statement from Washington detailed the type of proposition which the Commission hoped it would receive from industry. February

Fig. 1—Aerial view of site of Duquesne nuclear power plant

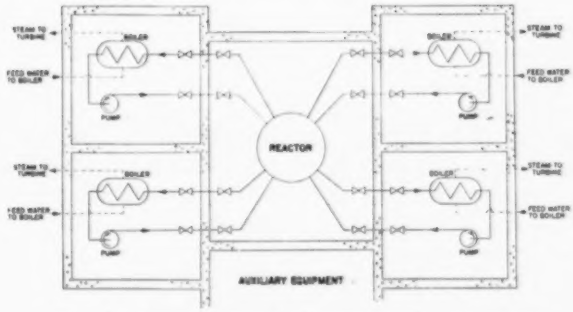


Fig. 2—Arrangement of main coolant system

15, 1954, was set as the deadline for submitting proposals. On March 14, following the receipt and analysis of nine proposals, the Commission announced that an offer made by the Duquesne Light Company was most favorable to the Government and would be accepted. The offer stipulated that Duquesne would furnish a site for the entire PWR project, that Duquesne would build an electric generating plant, that it would contribute $5 million toward the cost of the reactor plant, and that it would operate the overall plant at no cost to the Government. In addition, Duquesne will purchase steam produced by the reactor plant at certain specified rates which vary from 48.3¢ per million Btu the first year to 60.3¢ per million Btu the fifth year.

Location of Plant

On April 12, 1954, the Commission announced that this first large-scale atomic power plant will be built near the village of Shippingport, Pa., on the south bank of the Ohio River about 25 airline miles from Pittsburgh. Fig. 1 shows an aerial view of the site.

When Westinghouse commenced work on the primary plant, we were given the following general specifications:

1. Generation of at least 60,000 kw of useful electric energy.
2. Use of light-water-cooled and moderated, slightly enriched uranium-type reactor.
3. 600 psig saturated or higher steam conditions.
4. Fuel element life as long as possible between chemical reprocessing.
5. Refueling with minimum shutdown period.
6. Simplified reactor control system.
7. Conventional central station steam, electric, and other auxiliary systems.
8. Central-station-type turbine and electric generating equipment.
9. Commercial standards of equipment.
10. Use of concrete for shielding.
11. Minimum possible construction cost of the plant.
12. Minimum possible operating cost of the plant consistent with the above requirements.

As we analyzed our task, we saw that our severest problem centered upon development and design of the nuclear core. The two major aspects of this problem involved, first, development of suitable materials for the reactor and, second, development of basic physics design data and relationships capable of being used to calculate the nuclear design of the reactor core. As of mid-1953 we knew of no fuel material having corrosion-resistance characteristics and radiation stability which showed promise of meeting the conditions laid down in the specifications. Moreover, the general theory and the calculation techniques available at the time were clearly insufficient to serve as a foundation for design of the nuclear core.

Development Program

We therefore undertook a vigorous development program to attack these key materials and physics problems. On the materials side, we gave priority to the production, test and study of many potential fuel materials. A considerable effort went into the development of suitable structural materials and the fabrication of fuel into various shapes. An extensive in-pile test program was formulated for testing both sample materials and sample fuel elements. This work involved the design, fabrication and installation of several high-temperature, high-pressure test loops for use in the Chalk River and MTR reactors.

The physics program primarily consisted of constructing critical assemblies, plus the analytical work required to analyze test results and translate these into a practical and economically attractive nuclear design.

The bulk of the effort on reactor design was aimed at developing information necessary to choose a fuel element shape and to establish the thermal design of the reactor. This program involved preparing a number of different core designs associated with various fuel element types. It involved heat transfer studies to develop the basic data required to prove the design; and here we made use of a special fuel element burnout test loop. We also conducted a survey and study of various reactor control techniques.

In addition, we started preliminary design of the primary coolant system, looking toward determination of the number and size of primary loops, the methods to be used in constructing components and preparation of specifications for long delivery items. We also began work on site design, plant layout, the plant electrical systems and plant control.

The basic design of the PWR plant is now and for some time has been an established reality, in keeping with the general specifications which the Commission laid down.

Design of Coolant Systems

The main coolant system, which serves both to absorb heat generated by the reactor and to deliver heat to the steam generators, will consist of four loops operating off the reactor vessel, as shown in Fig. 2. Each loop, in turn, consists generally of a pump, a steam generator, shutoff valves and interconnecting pipe. The pumps continuously circulate coolant water between the primary system and the steam system. It consists of a water-to-

water heat exchanger, and a steam drum and separator. The shutoff valves permit us to isolate one loop if it is not required, or to repair one loop while the other three loops are operating.

The water in the primary plant will circulate at a pressure of some 2000 psig to prevent boiling in the core and to eliminate cavitation problems. The average temperature of the primary plant water is maintained at about 525 F.

The primary coolant loops are so designed that the rated plant output is produced with three of the four loops operating. The fourth loop can be operated if desired, but will normally serve as a spare. The loops divide the load equally, and the steam generated by each is fed to a steam header and delivered to the turbine. To produce 60,000 kw net with 3 loops operating, the pump in each loop circulates water at a rate of about 16,000 gpm. This makes a total of about 48,000 gpm through the reactor. About 1000 hydraulic horsepower is required to circulate the water in each of the three loops. All surfaces of the primary coolant water probably will be made of stainless steel. All components will also be designed to prevent leakage of the primary coolant water from the primary system.

In addition to the main coolant system, the primary plant involves a number of auxiliary systems. These accomplish such necessary functions as maintaining the primary system pressure at 2000 psig, filling and draining the primary system, purifying the water, providing for control of the reactor, dissipating the decay heat of the reactor after shutdown, etc. Preliminary designs of many of these systems have been prepared.

The primary water is maintained at 2000 psig by a pressurizing tank which floats on the system and is connected to one of the reactor outlet pipes. This tank is normally filled with about equal volumes of water and saturated steam at more than 600 F. The head of steam is maintained by electrical heaters in the water. Load changes are accompanied by some volume change of the primary water. The head of steam expands or contracts to accommodate this water volume change.

Reactor Core

The most interesting and highly developmental part of the plant is, of course, the reactor core. It will consist of a geometrical pattern of closely spaced fuel elements. The heat generating material will be slightly enriched uranium, that is, uranium containing a slightly higher amount of the 235 isotope than natural uranium as mined from the earth. More than 10 tons of uranium will be used in the first core. The fuel elements will be protected by a corrosion-resistant material designed to prevent the coolant water from becoming contaminated with particles of uranium and fission products.

These fuel elements will be formed into a right circular cylinder about 6 ft in diameter and $7^1/_2$ ft high. The maximum fuel element surface temperature will be less than 636 F, the boiling point of water at 2000 psig. The maximum heat flux will be over 350,000 Btu per sq ft per hr, and the average power density will be about 45 kw of heat per liter.

The reactor container, as well as the entire plant, is being so designed that fuel elements of various shapes and materials of various types can be used in cores following after the first core. Such flexibility will add somewhat

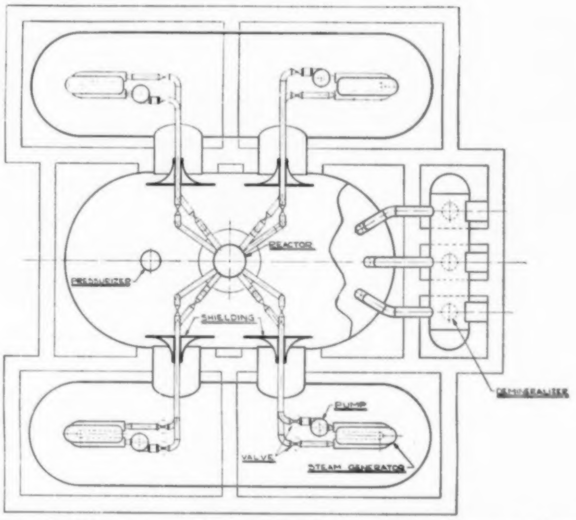


Fig. 3—Plan view of proposed layout for primary plant

to PWR costs, but we think that this feature is appropriate to a developmental plant and that it may help importantly in advancing atomic power technology.

The reactor vessel, which contains the core, will be built large enough to accommodate cores physically bigger than the first one. Here is another aspect of the flexibility feature just mentioned. The vessel shell will be about 9 ft inside diameter and have an overall height of over 25 ft. This shell will consist of carbon steel clad with stainless steel. The cylindrical wall of the vessel will be penetrated by the four inlet and four pipe outlet connections for the four main coolant loops. A contract for the design and manufacture of this vessel is being negotiated.

Steam Generators

The steam generators will consist of two major components: First, the heat exchanger portion and second, the steam drum. The heat exchanger will consist of a bundle of stainless steel tubes, the ends of which are welded into heavy tube sheets. The entire assembly will be enclosed in a steel shell. Primary coolant will flow through the inside of the tubes. The steam plant feedwater will be fed into the shell side of the heat exchanger and will be converted to steam as it flows upward over the outer surface of the tubes. The steam thus generated will rise to the steam drum where it will be dried by passing through a conventional steam separator. The steam will leave the steam drum at 600 psia saturated. We have placed firm price orders for the four steam generators. The Foster Wheeler Corp. will build two and the Babcock and Wilcox Co. will build two. It is felt that the relatively small additional cost of splitting this order is more than justified on the basis of additional knowledge to be gained, since the two companies are using designs which differ significantly.

Auxiliary Equipment

The pumps will be single-stage centrifugal units driven by induction motors of the canned type. Use of canned motors permits elimination of the maintenance and leakage problems likely to be encountered if rotating seals were employed. The Westinghouse Atomic Equipment Department is now designing a prototype pump and mo-

tor which will be built and tested before manufacture of the final units. The PWR pumps will involve an output of about 1000 hydraulic horsepower, and an input of about 1200 kw.

The primary coolant stop valves will be of the gate type. At least some of these valves will be designed to permit remote operation. They will be hermetically sealed and will function hydraulically. A prototype main coolant valve is now on order from the Crane Company.

The primary coolant system pipe will be approximately 18 in. in outside diameter. It will be fabricated from stainless steel. It seems probable that the pipe and necessary elbows will be manufactured by rolling and welding stainless steel plate.

Control System

Regarding the nuclear control of this plant, we intend taking advantage of the inherent stability of pressurized water reactors as the basis for control during power changes. Due to the negative temperature coefficient which can be designed into such a reactor, the core will automatically maintain the temperature of water flowing through it at a constant value. Thus, if heat is removed from the primary coolant and if the coolant water temperature therefore decreases, the reactor automatically restores this heat by increasing its power output until the water temperature regains the original value. The reverse is true when the rate at which heat is being removed from the primary water is decreased. The reactor itself accomplishes this control automatically without the operation of any equipment.

The entire primary plant will be enclosed in a steel container to retain any radioactive materials which might escape from the plant as a result of an accident. Although such accidents are extremely improbable, safety requirements are such that, at least on this first plant, great precautions must be taken.

Fig. 3 is a plan view of a proposed layout for the primary plant showing the concrete shielding, the container housing the primary plant and the major plant components including the reactor, the pipe, main coolant pumps and the steam generators.

Figure p. 38 shows a preliminary artist's sketch of the plant. The plant components depicted are, from the left: a building for fuel handling, the atomic reactor and heat exchangers, the maintenance building and overhead traveling crane, the turbogenerator building, the switchyard containing transformers and circuit breakers, and transmission lines. In the right foreground is a building containing shop and administrative facilities.

As can be seen from the cutaway view, the reactor which provides the heat, and the heat exchangers which generate the steam, will be located underground in concrete and steel structures. These underground structures will provide protection to operating personnel and the surrounding area in addition to the many protective devices in the reactor itself.

Cost Estimating

Our experience to date on PWR has confirmed the difficulties of estimating the cost of a new reactor type without actually designing and building it. Recently we obtained, from the nation's most competent vendors, fixed-price sealed bids on the PWR steam generators and also on a prototype main coolant valve. Both bid invitations were based on complete performance specification. The bids received on each component varied by a factor of almost 5 to 1. With such variation in prices for the more conventional pieces of equipment, as quoted by qualified manufacturers, it seems clear that cost estimates on highly experimental items such as core fabrication and reprocessing are not estimates at all but merely guesses.

Those of us engaged in the design and manufacture of the PWR reactor can readily see how construction of this first plant will point the way to major reductions in both the capital and operating cost of later plants. As our technical requirements become better known, we can prepare firm specifications for all equipment and therefore benefit by competitive bidding across the board. As more experience is gained, we expect to reduce the need for such costly materials as zirconium and stainless steel. We are also confident of finding ways to eliminate the need for certain expensive safety devices.

As we learn more about the physics of slightly enriched water-reactors and more about the technology of reactor materials, we know that we can bring about manyfold reductions in the costs of fuel processing. It will be necessary to build the first core largely by hand, ironing out manufacturing difficulties as they arise. Those of you familiar with manufacturing operations will recognize that process development is expensive and that it is not economical to tool-up for routine manufacturing until requirements are firmly established through experience. As time passes, however, we will unquestionably rely less and less upon hand labor and more and more upon automatic machines.

Furthermore, with additional knowledge and experience, we are sure that it will become possible to extend core life, thus reducing fuel costs by spreading fuel fabrication and reprocessing expenses over many more kilowatt-hours. We anticipate finding ways of greatly decreasing the amount of uranium 235 used per kwhr.

As you observe from these remarks, we at Westinghouse believe in the wisdom of building a full-scale pressurized water reactor. We believe that the design minimum of 60,000 kw is a sensible specification for the first plant, taking into account cost factors and the existing state of technology. Later plants will certainly be more economical at a higher power level. Likewise, we are glad that PWR is an all-civilian reactor, since this permits exploration of the pressurized water approach to industrial power without confusion or dilution either of the objective or the end results.

Design Philosophy

With our eye on costs, we are approaching the PWR exactly as you would expect from the philosophy that has been expressed. Enriched uranium is expensive, and so we have chosen to employ uranium of the least enrichment consistent with other technical considerations. Heavy water is expensive, and its limited advantages, in our opinion, do not offset the extra cost; hence we have chosen to use ordinary water. Fuel reprocessing is expensive, and we therefore seek the longest attainable life span for each core loading and in addition we are striving for the maximum use of converted material. This objective calls for high fuel burnup including burnup of the plutonium produced as our reactor operates. The PWR will be a converter, that is, it will convert fertile material

to fissionable material in the core.

No one has ever built a power reactor like this before. The slight enrichment, the long core life span, the deliberate intent to burn plutonium after it is generated through reactor operation, the use of ordinary water in conjunction with the other features, and additional matters which I am not at liberty to disclose—each of these objectives, considered separately, is without precedent, at least in the free world. Considered in the aggregate, they mean that we are struggling to take a long stride into the unknown.

As we know more about reactors of this type, more and more of the power will come from burning plutonium generated in the reactor after operations commence. In fact, there is no reason, in principle, why pressurized water reactors cannot become breeders. But trying to build such a feature into Plant Number One, along with all the other unprecedented features, would tack on years to the completion date. (*Editors Note: See "Refresher Notes on the Initial . . . Proposal" below.*)

I have heard it claimed that building an H-bomb is a tougher job that building an A-bomb—but that the scientists could not even consider the H-bomb unless they had first acquired A-bomb experience. This is our situation with the PWR. Developing it will present many tough problems; but we could hardly even dream about a practical, attainable PWR without our previous experience in building pressurized water submarine plants.

At the same time we do not claim to know, and we do not believe anyone can justly claim to know, which reactor type will ultimately turn out to be most satisfactory. In fact what is considered the *best* plant will certainly vary with time. Certainly very few techniques in any field have maintained a *first* position over extended lengths of time. As a nation we are still only scratching the surface of atomic power technology. The evidence required for any sort of solid judgment is just plain lacking. For this reason we welcome the Atomic Energy Commission's recently announced five-year program for industrial power reactor development. The Commission's policy of exploring the five approaches that seem most promising today is certainly right; for this is the only practical way to find out the advantages and disadvantages of each. If any of the techniques after evaluation appear practical I trust they will be followed by large-scale plants as in the case of the PWR.

Refresher Notes on the Initial AEC-Duquesne Light Co. Proposal

On March 14, 1954, when Lewis L. Strauss, chairman of the Atomic Energy Commission, announced the decision to negotiate with the Duquesne Light Co. for participation in the construction and operation of the nation's first full-scale central station nuclear power plant he also revealed the main points of the Duquesne proposal.

This proposal, incidentally, was one of nine submitted and it spelled out the Duquesne Co.'s participation:

(1) Furnish a site for the entire project and build and operate a new electric generating plant at no cost to the government.

(2) Operate the reactor part of the plant and bear the labor costs thus entailed.

(3) Assume $5 million of the cost of research, development, and construction of the reactor portion of the plant.

(4) Pay the Commission at the rate of 48.3 cents per million Btu's of steam used in the turbine for the first year; the rate increasing annually until it reaches 60.3 cents in the fifth year.

(5) Waive any reimbursement by the government of costs incident to termination of the contract.

At the same time Chairman Strauss estimated that, including revenues from the sale of steam generated by the reactor, the Duquesne Light Co.'s proposal would reduce by about $30 million the expenditures the government would have to make during the period of construction and the first five years of operations if it undertook the full cost of the project.

Somewhat later the Atomic Industrial Forum, Inc., New York, N. Y., in its Forum Memo, Volume 1, No. 5, summarized the AEC 5-year nuclear reactor program released this past February. They had this to say about the PWR or Duquesne Light Co. reactor:

Timing. Construction is expected to begin during the fiscal year 1955, which starts July 1, and the plant should be in operation within 3 or 4 years. The Congressional Joint Committee says 1957 definitely.

Costs. The Duquesne Light Co. proposal of payments for steam used in the turbines will amount to about 8 mills per kwhr of net output of the generator.

The electric generating portion of the plant will probably cost $12 million over and above the $40 million for the reactor. The Joint Committee puts the total research, development, construction and operating cost of the project for the next five years at $85 million.

AEC manager Nichols told the House Appropriations Committee: "I believe . . . with this existing set-up we may get as low as 12 mills if we can increase the life of the fuel rod assembly. . . ."

Stone & Webster Selected as Architect-Engineer for Duquesne Power Reactor

Selection of Stone & Webster Engineering Corporation, Boston, Massachusetts, to perform architect-engineering services associated with the design of the nuclear portion of the pressurized water reactor to be constructed at a site near Shippingport, Penna., was announced on June 1 by the Atomic Energy Commission.

Stone & Webster will be a subcontractor under the Westinghouse Electric Corporation which has responsibility for development, design and construction of the nuclear portion of the PWR project under its prime contract with the Commission. As the Commission has previously announced, the turbine-generator portion of the plant will be designed and constructed by the Duquesne Light Company of Pittsburgh, Penna.

The subcontract with Stone & Webster will provide for the reimbursement of actual costs from Government funds and the payment of a fee of $1.00 for services.

Work to be performed by Stone & Webster will include design and preparation of plans and specifications for the reactor foundations, reactor containing structure, fuel handling facilities and certain other auxiliaries required for operation of the plant.

Steam Purity Determination
III. Interpretation of Test Results

In previous articles, the evaluation of current steam purity test values was discussed, and methods of sampling and testing were suggested to supplement the usual determination of steam purity. In this article, selected examples of test results are discussed in some detail to illustrate the analysis and interpretation of steam purity test data. These examples do not include all of the possible cases in the field of steam testing nor are they presented as ideal patterns of test procedure. It is hoped that they will suggest viewpoints to the test engineer which will assist him in devising special test methods and in analyzing his test results.

By P. B. PLACE
Combustion Engineering, Inc.

YEARS of testing boilers, operating under a wide variety of operating conditions, have built up a background of observations from which the author draws liberally in the interpretation of an individual case. In all cases, the assumption is made that results should be logical, should conform with results obtained for other tests under similar conditions, and should not be accepted on face value simply because they were obtained by a standardized procedure.

Development of foaming in the boiler is perhaps the most common source of carryover but one that is often questioned, especially if the foaming develops at relatively low concentrations. Foaming in a boiler can be easily and positively identified by use of special drum sampling and suitable test procedures. Fig. 1 shows typical results of such a study, p 44.

Study of Foaming

In test *A*, the normal range of operation is covered with a low, non-foaming boiler water concentration of about 550 ppm. Note that dryer inlet steam conductivity is low and constant and that the ratio of this conductivity over the conductivity of the boiler water indicates a moisture content in the steam to the dryer of ten per cent or less. This amount of moisture is within dryer capacity limits and saturated header steam is satisfactory at about one mmho conductivity degassed. Test *B* was then made at a higher concentration of about 1500 ppm. Note that dryer inlet sample conductivity now registers conductivity peaks of over 500 mmhos which are considerably higher than a 3 to 1 increase in boiler water concentration would suggest. The variations and peaks in this conductivity, and in the conductivity ratio, indicate initial development of foaming although header steam conductivity remains unchanged and is constant during the test period. A third test, *C*, was made with concentration increased to 2300 ppm. The results show radical variations in dryer inlet sample conductivity and ratio values even though the rating is steady and somewhat less than full load. Dryer inlet values of nearly 1500 mmhos, and ratios of 0.3 to 0.5, indicate excessive moisture delivery to the dryer and potential danger of carryover. Such carryover occurred later but only to extent of 3.7 mmhos which would not alone be evaluated as being due to foaming. Operating under such conditions, the boiler would be sensitive to small changes in rating and water level. Without the evidence of satisfactory performance at the lower concentrations, the cause of the carryover might have been ascribed to mechanical features of the boiler rather than to the conditions that produce foaming.

The carryover with which we are concerned is boiler water, and since the concentration for test *C* is fourfold that of test *A*, then if one mmho is correct for the steam for test *A*, this value should be in the order of four mmhos for test *C*. It will be noted that in tests *A* and *B*, header steam conductivity is somewhat higher at the lower ratings. This is probably because the higher percentage of continuous blowdown at the lower rating required a higher rate of feedwater flow to the boiler resulting in an increase in gases in the steam. Although the absolute impurity in the steam cannot be stated, the test results indicate that it is appreciably less than the standard evaluation for one mmho conductivity.

Similar Study without Degasification

Fig. 2 shows the results of a similar study in which boiler outlet steam was not degassed. At a concentration of 450 ppm, note that boiler outlet sample conductivity was seven to eight mmhos but that dryer inlet sample conductivity was only slightly higher at eight to ten mmhos. The latter increases slightly with increase in rating, but the amount of spray delivery to the dryer is so small as to constitute a very minor burden on this portion of the drum internals. Increasing the boiler water concentration to about 1800 ppm in the second test shows no appreciable change in boiler outlet steam sample conductivity but does cause a small increase in dryer inlet sample conductivity with increase in rating. This increase to 40 mmhos represents an increase in moisture in the steam to the dryer to less than $1^1/_2$ per cent, an amount far below dryer capacity and not indicative of potential carryover. In evaluating this increase in dryer inlet conductivity, it should be noted that the

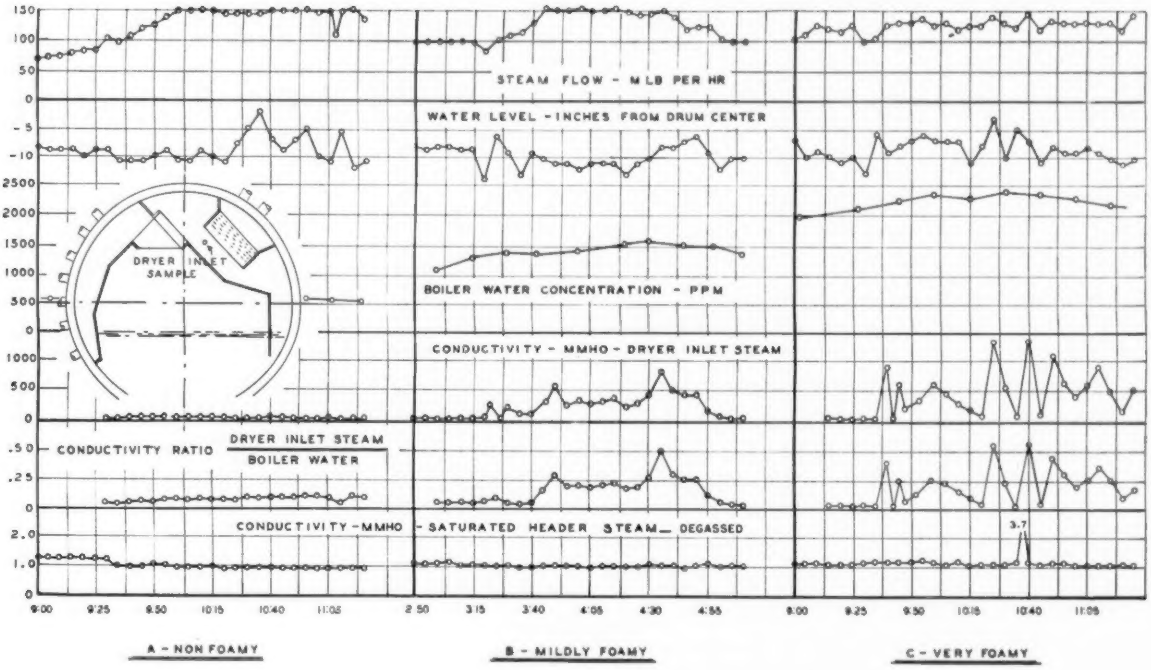


Fig. 1—Development of foaming with increase in boiler water concentration

indication of boiler water carryover to the dryer is about four times that of the first test.

In the third test shown in Fig. 2, boiler water concentration is increased to about 2800 ppm and severe foaming is evident from the test results of both samples. The space between the water level and the drum internals is practically filled with the foam blanket on the water, and the dryer inlet sample registers high conductivity whenever the water level rises above drum center. Note that between foam surges into the dryer, the dryer inlet sample conductivity returns to a base value similar to that for the second test. In this case, it is likely that if the test were repeated with a two to three inch lower water level, the results would be similar to those of the second test with little if any evidence of foaming.

Experience with Steam Dryers

Aside from the two carryover surges in the boiler outlet steam, the conductivity of this sample is only slightly higher than for the previous tests in spite of more than a sixfold increase in boiler water concentration over the test periods. That the undegassed conductivity represents very pure steam is indicated by at least two observations. First, a sixfold increase in boiler water concentration should have resulted in appreciable increase in outlet steam conductivity if any appreciable carryover was involved. Second, the dryer's ability to separate spray and foam, as demonstrated in the second and third tests, should have resulted in low boiler outlet sample conductivity in the first test when dryer inlet conductivities were low and constant.

Experience with dryers has indicated that these devices function as filters and, within their design limitations, their capacity is not a function of rating. Furthermore, when dryer outlet conductivities are unaffected by changes in boiler water concentration, it is evidence that separation of boiler water must be practically complete. Otherwise, the conductivity of any small amount of moisture which escapes the dryer, and which we normally determine as impurity in the outlet steam, must increase with increase in boiler water concentration.

Fig. 3 illustrates another method of analyzing test data to demonstrate the development of foaming in the boiler. The principal value of drum samples is in indicating the wetness of the steam, and therefore drum sample conductivity values are significant only when correlated with boiler water concentrations. The sudden and considerable increase in the conductivity of a sample when foaming develops is due to the increase in wetness of the steam. Considerable boiler water is trapped in the foam mass so that the sample is more that of an emulsion than of a mixture of steam and thin-walled foam bubbles. Thus a radical change in the character of the moisture in the steam occurs when it changes from a spray mixture to a foam mixture and this change can be recognized by the corresponding change in sample conductivity.

In Fig. 3, the per cent increase in conductivity of a drum sample and of the boiler water is compared for a period of feeding chemicals to the boiler. Note that for the first 20–25 minutes of chemical feed, the rate of increase in conductivity for both samples is similar, but that at the end of the period, the drum sample conductivity increased some 2000 per cent as compared with only a 200 per cent increase in boiler water conductivity. The sharp rate of increase in drum sample conductivity indicates the development of foaming and disproportionate increase in wetness of the drum steam sample. This test was made at constant rating and water level and the data obtained without any change in conductivity of the boiler outlet steam.

Cases of Leakage Carryover

In cases where there is leakage around a dryer or similar final stage of purification, it would be expected that the conductivity of the outlet steam would register the contamination and that it would vary with boiler rating. The conductivity would, of course, also vary

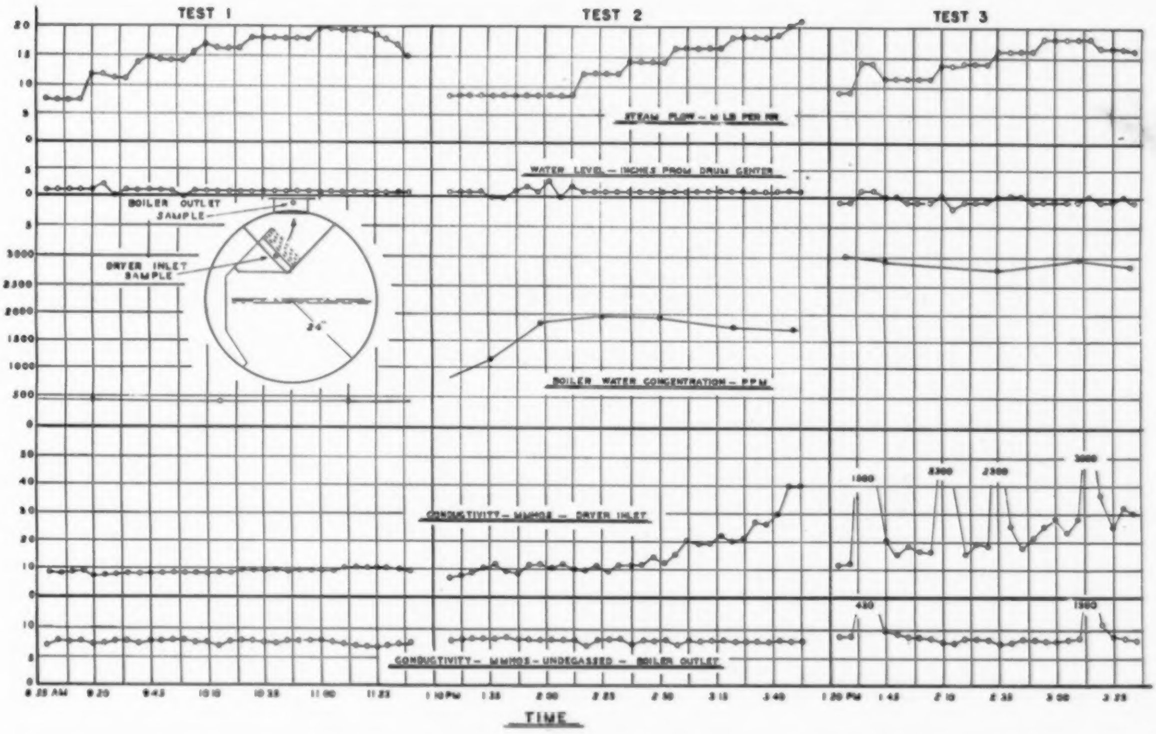


Fig. 2—Development of foaming with increase in boiler water concentration; boiler outlet steam not degassed

with boiler water concentration. If the leakage is small and localized, or if it happens to be on the opposite side of the boiler from where the steam sample is taken, it may not be detected in the steam sample conductivity record and local or traverse sampling may be necessary to trace it down. In many cases, however, leakage is quite evident as shown in the test results of Fig. 4. In an interconnected boiler-turbine system, washable turbine deposits indicated carryover. Tests were made on all three boilers with special attention to dryer inlet, saturated header, and saturated header drain line steam samples. The drum and header drain samples were not degassed and the standard header sample was partially degassed. Boiler water concentrations were kept normal and similar for all tests, but rating was varied since leakage should vary with the rating.

Dryer inlet sample conductivities showed no evidence of uncontrolled foaming in the boiler, so occasional foam-

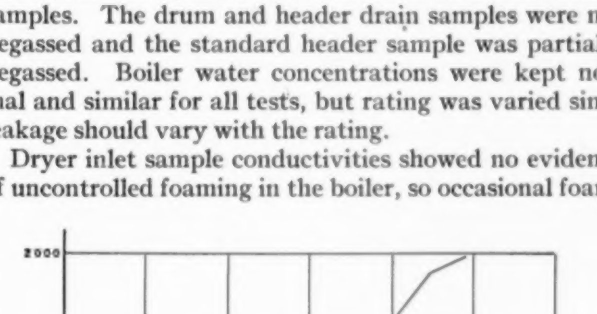


Fig. 3—Foaming conditions purposely developed by special chemical feed

over could be discarded as cause of the turbine deposits.

Of the three boilers, Nos. 1 and 2 showed evidence of leakage carryover. Note that the conductivity of both the header and header drain samples for these two units varies with the changes in boiler rating but that the amount of leakage carryover is very small. The total leakage in No. 1 boiler is less than in No. 2 boiler but appears to be localized at one side of the unit where it is more easily detected in the special drain line sample.

It is interesting to note that inspection of these units before the tests were made revealed minor leakages in all three units. The leakages were sealed but the turbine deposits continued. These subsequent tests indicate that a more careful inspection of boilers No. 1 and No. 2 was necessary.

Effect of Gases on Conductivity

In most cases, the effect of gases on the conductivity

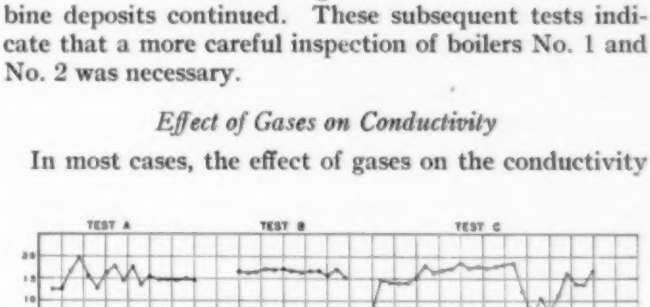


Fig. 5—Effect of chemical feed on conductivity

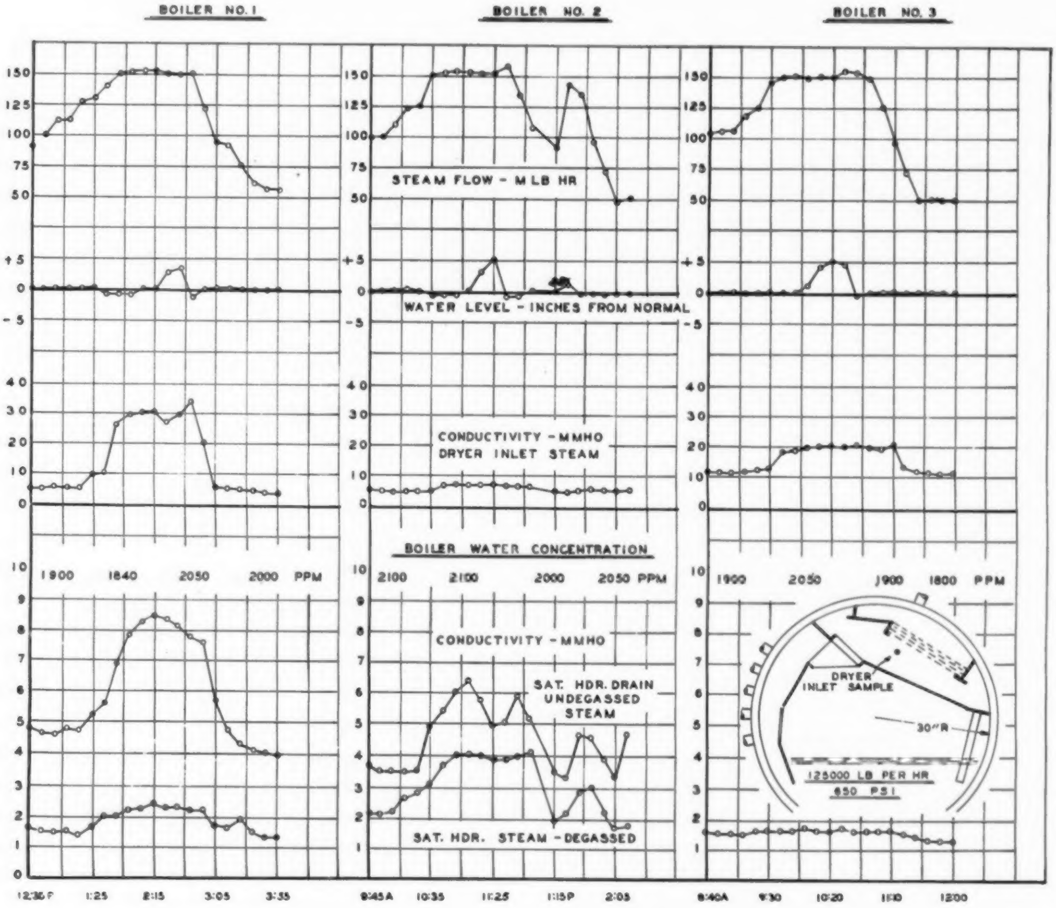


Fig. 4—Tests on three interconnected boilers to locate source of carryover

record of the steam sample is readily recognized. In a few cases, the effect may be paradoxical and confusing. The tests shown in Fig. 5 illustrate different effects resulting from feeding chemicals to the boiler. Steam samples were not degassed so that the effects are magnified, but similar results have been noted where sample conductivity averaged one mmho or less.

In test *A* shot feeding chemical to the drum resulted in increase in outlet steam conductivity from $5^1/_2$ to 11 mmhos. This increase might have been interpreted as a small foamover induced by chemical feed, but dryer inlet test values show no evidence of foaming and are practically the same as boiler outlet test values. The similar effect of chemical feed on both samples is clear evidence of gas evolution. The chemical mixture included an amount of carbonate.

In test *B*, dryer inlet sample conductivities are relatively low with no evidence of foaming with increased boiler water concentration. In this case, however, shot feeding chemical to the drum results in a decrease in sample conductivity. The chemical was alkaline but contained no carbonate. The increase in boiler water alkalinity may have reduced the normal CO_2 evolution from the feed water so that less gas effect registered in the steam conductivity but this effect is usually temporary.

Continuation of this test in *C* at higher concentrations, shows a second drop in boiler outlet sample conductivity induced by feeding chemicals. In this case, however, foaming has developed as indicated by dryer inlet conductivity fluctuations. Foamover occurs when water level surges five in. above drum center during an increase in load.

There is considerable variation in undegassed steam conductivity. It is confusing to note that this conductivity tends to decrease with increase in boiler water concentration. For test *C* it is evident that the normal impurity in the steam can be no higher than indicated by the lowest conductivity value obtained at 2:00 p.m. when rating and concentration were at a maximum. Laboratory determinations on spot steam samples supported an estimate of less than $^1/_2$ ppm impurity.

This decrease in sample conductivity during chemical feed has also been noted in central station operation where the conductivity record was normally constant at one mmho. Shot feeding enough chemical to raise boiler water concentration 250 ppm resulted in temporary decrease in conductivity from one mmho to 0.7 mmho.

Minor gas effects on conductivity can sometimes be noted during rapid changes in load that are great enough to cause change in water level. When rating is decreased suddenly enough to result in a drop in water level, the feedwater flow is temporarily increased to bring level back to normal. This excess of feed flow over steam flow causes a small increase in gas evolution which may register as increase in sample conductivity. Thus the steam purity record may show the paradox of improvement when rating is increased and vice versa.

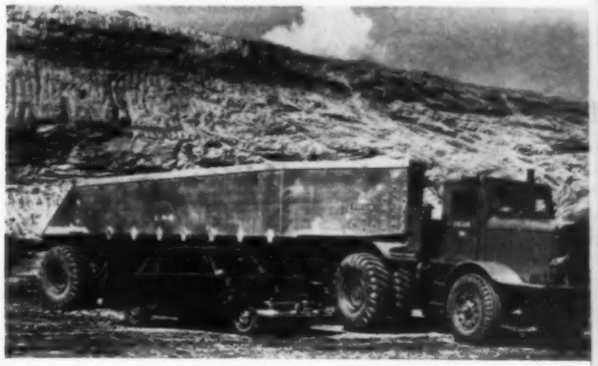
Conclusion

Analysis of steam purity test results, supported by additional data obtained by special sampling, yields a number of observations that serve to build a background for logical interpretation.

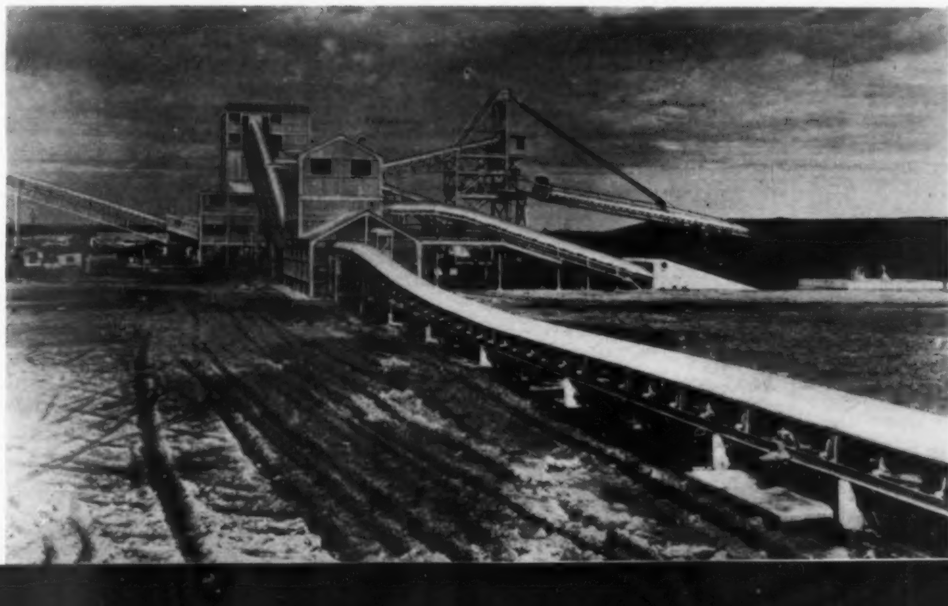
Photographic Visit to the Sandow Power Plant, Rockdale Works of the Aluminum Co. of America, Milam County, Texas

Aerial view of Rockdale Works, showing Sandow Power Plant at upper center and created lake in background.

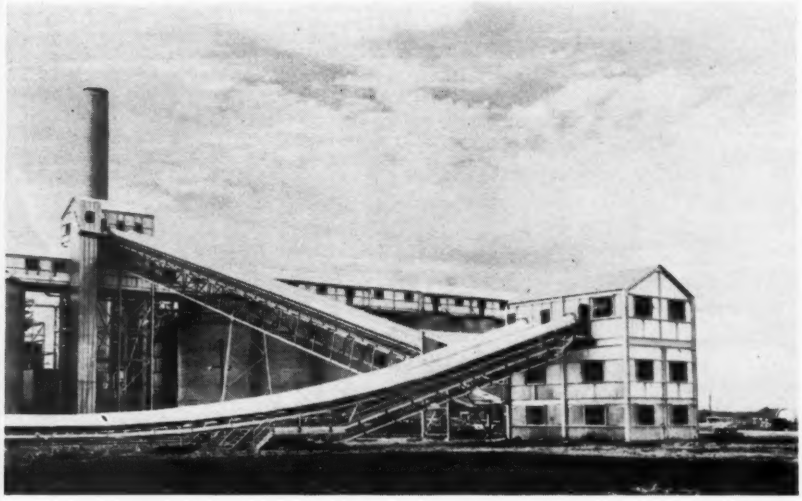
Dragline excavator shown stripping overburden from nearby Milam County deposits. This electrically operated dragline has a 220-ft boom and a 35 cu yd bucket.



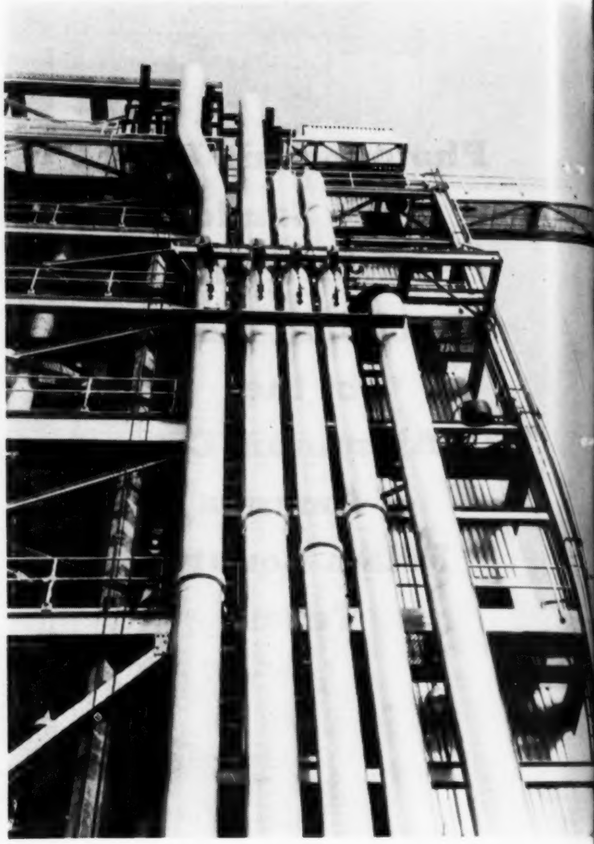
One of seven trucks which haul lignite to conveying system. The corroson-resistant aluminum alloy trailer bodies have a capacity of 61 cu yd.



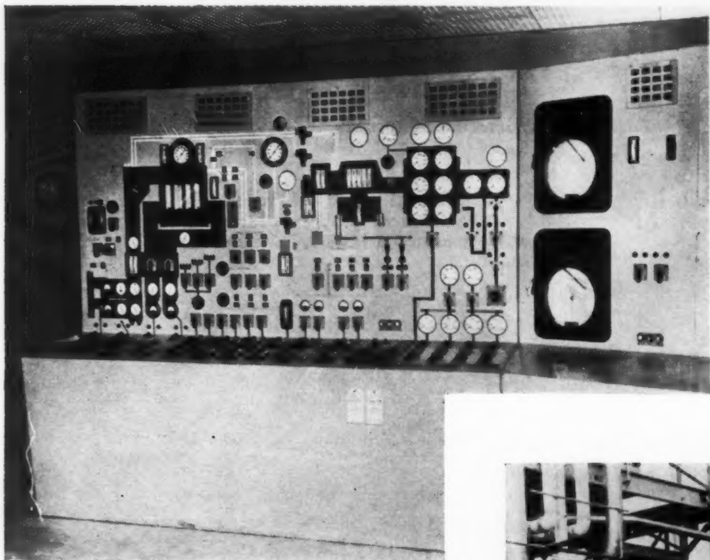
General view of lignite conveying system



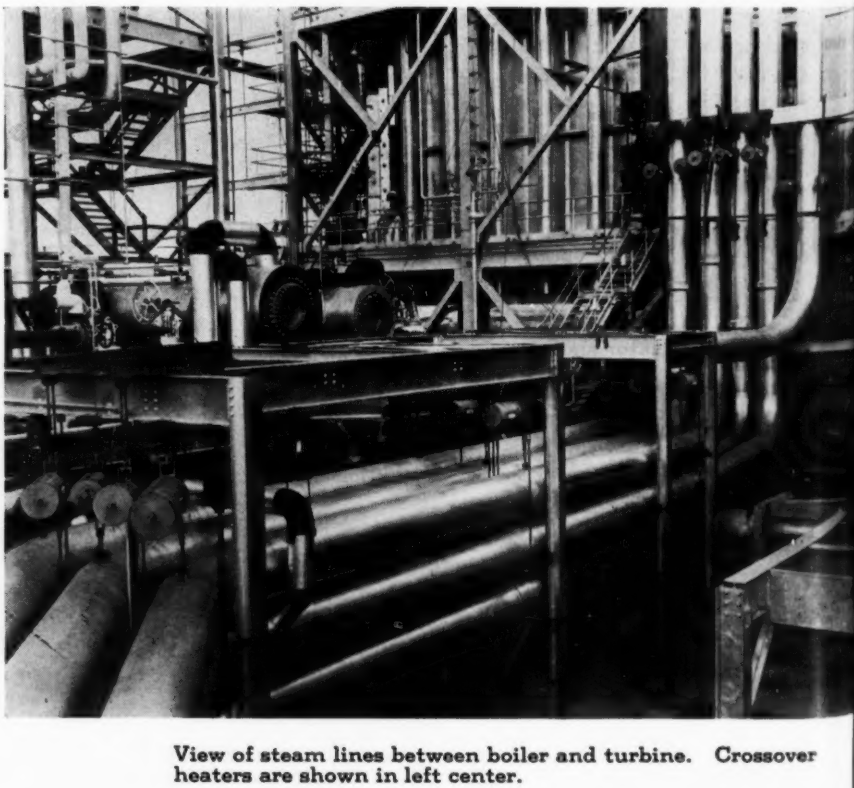
Lignite conveyors leading to raw lignite storage bins



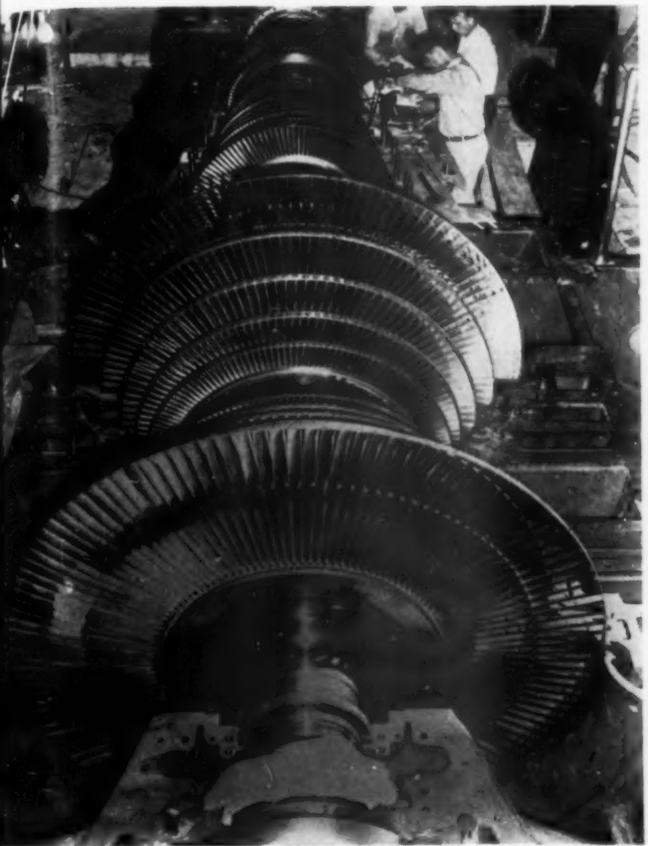
Aluminum-covered main steam lines on No. 1 boiler unit



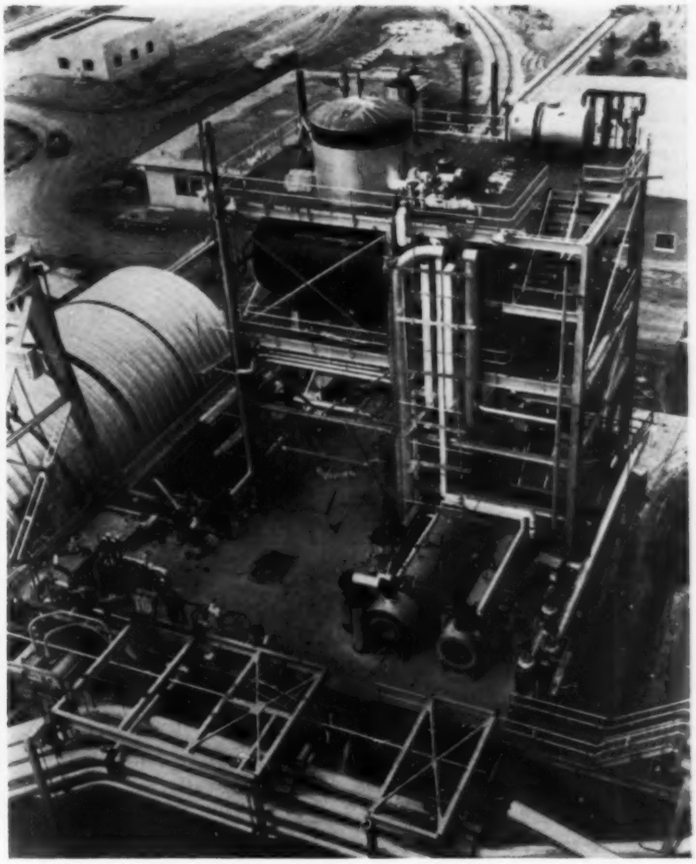
Boiler and turbogenerator control board



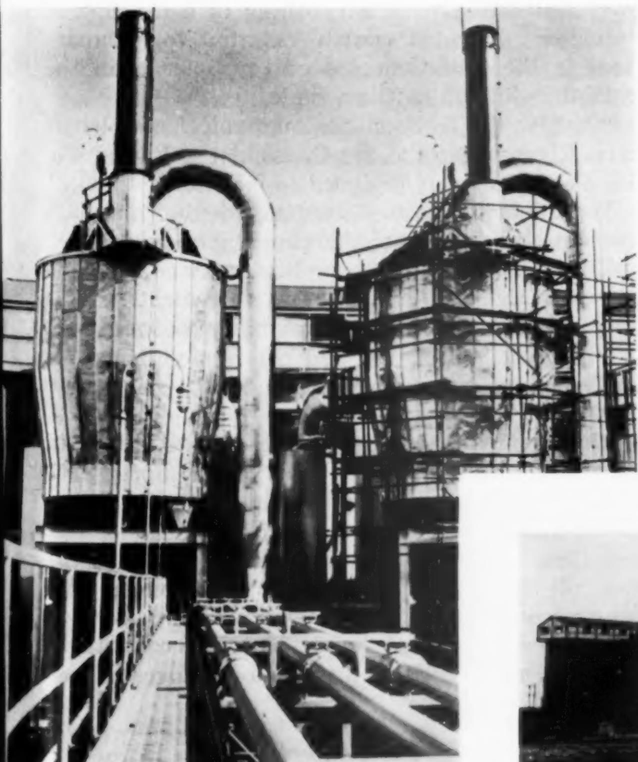
View of steam lines between boiler and turbine. Crossover heaters are shown in left center.



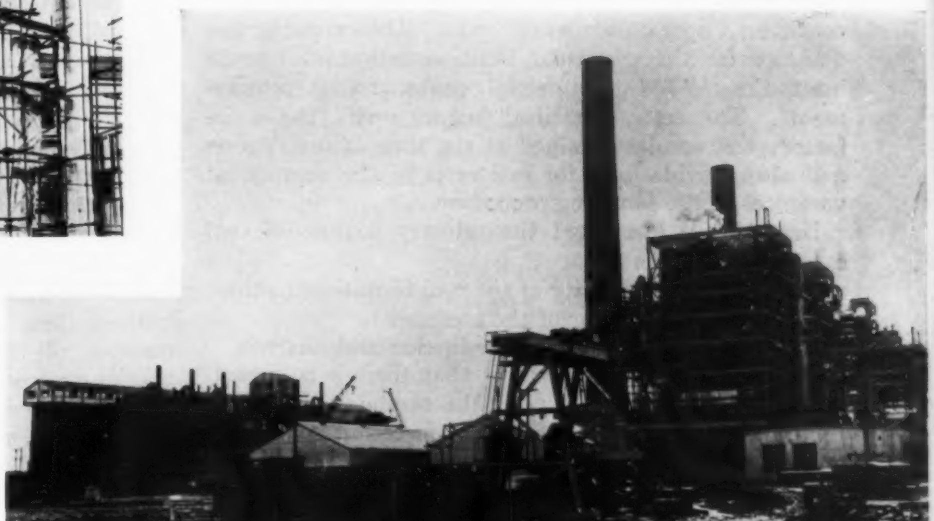
Turbine rotor being assembled in one of the generating units



Nearly completed deaerator tower



View of the first two lignite dryers



General view of power plant and lignite-processing facilities, looking over the lake intake structure

*Tests of Accuracy of a Mechanical Coal Sampler**

By R. L. CORYELL,† F. J. SCHWERD,** and E. J. PARENTE††

Consolidated Edison Co. of N. Y., Inc.

The ASTM recommendations to assure accurate mechanical sampling of coal limit sample lots to 1000 tons. Consolidated Edison Co. of New York ran a series of accuracy tests on sampling procedures that indicate sample lots of mixed coals can be raised to as much as 13,000 tons with no increase in number of 50 lb increments over a 1000 ton lot and still give satisfactory accuracies.

THE theory and design of coal sampling procedures have received much attention over the past two decades. Both American and British standards for sampling of coal shipments are generally acceptable. However, some large coal users in the United States have found that, to comply with present ASTM standards, they must take excessively large gross samples with their mechanical samplers which of necessity take very large increments.

Published reports (1) of earlier sampling investigations have indicated that increasing the size of increments permits decreasing the number of sample increments, and investigation of this has been a secondary purpose of making these tests.

In cooperation with the other users of mechanical coal samplers reporting at this Symposium, the Consolidated Edison Co. of New York, Inc., recently tested the performance of a sampling unit that had been in continuous operation for 14 years. This sampler was designed for the particular location and conditions to meet the ASTM commercial coal-sampling requirements. The tests, described below, verify the satisfactory test results obtained at the time of installation and also provide data for estimates of the component variances in the sampling procedure.

Bertholf (2) has listed the primary sources of coal sampling errors as:

1. The true variability of the coal from time to time.
2. The random error of the increment.
3. The combined errors of reduction and analysis.

It naturally must be assumed that there is no significant bias in any of the steps in the sampling procedure. In the design and installation of a mechanical sampler, it is essential that tests be made for such bias and that any bias found be eliminated. Later, regular tests must be made to confirm the absence of any significant bias.

The "true variability" of the coal in this study is actually the variability of a mixture of several coals in each shipment. These mixtures include medium- and high-volatile coals with ash contents ranging from 6 to 13 per cent by weight. Theoretically, the sampling of mixed coals is more difficult than sampling the individual coals. It would therefore appear that the sampling of the mixed coals presents the most severe conditions for the mechanical sampler.

The "random error of the increment" is a measure of the difference between the increment and the true average of its immediate neighborhood. It has been shown that the random error is affected by the distribution of particle size and the free impurity content of the coal and that this error becomes smaller with increasing size of the increment.

In testing a particular mechanical sampler where the increment size is usually fixed, it is necessary only to obtain a single value which includes the combined effect of the variability of the coal and of the increment. This value is termed "sampling variance" in this report.

Errors of reduction and analysis are also of major interest in testing any sampling procedure These errors will be reflected in the overall accuracy obtained. Hence it is particularly necessary to estimate these errors in connection with any testing of a mechanical coal sampler. It is, of course, essential to eliminate any bias in the operation of a coal sampler or in the subsequent reduction of the sample.

Accordingly, the tests on the mechanical sampler at the East River Station of the Consolidated Edison Co. of New York, Inc. were designed to include:

1. Preliminary tests to determine whether any bias was present at any stage of the sampling operations.
2. Determination of the sampling variance from the deviations of the individual sampler increments. This variance includes the actual variability between the successive small lots of coal and the random error associated with the size increment taken by the mechanical sampler.
3. Measurement of the variance due to errors in reducing the gross sample to a laboratory pulp.
4. Measurement of the variance due to small random errors in laboratory analysis.

From these variances, an estimate can be made of the number of increments required for commercial and special purpose sampling. These variances are based on the ash analysis of the coal samples since this constituent provides the most sensitive measure of changes in coal quality.

Mechanical Sampling

At the East River Station, all coal is crushed to pass a $1^1/_2$-in. screen in two unloading towers and is then delivered to two 36-in. belts. Sampling is effected

* Presented before the Fifty-Seventh Annual Meeting of the American Society for Testing Materials, Chicago, Ill., June 13-18, 1954.

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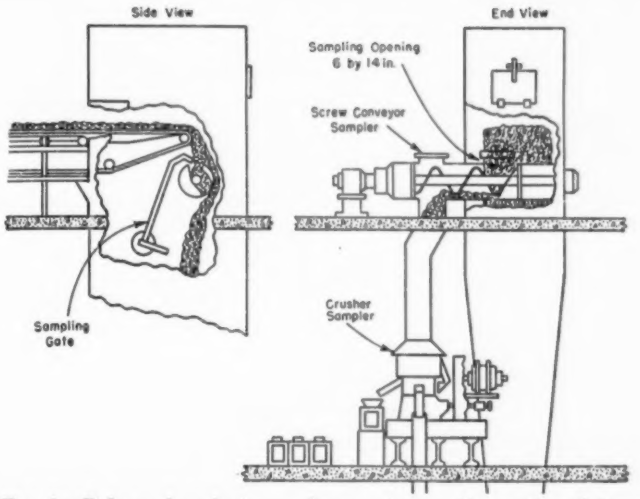

Fig. 1—Side and end views, above, picture the motor-driven screw conveyor that draws its sample from the middle of the coal stream

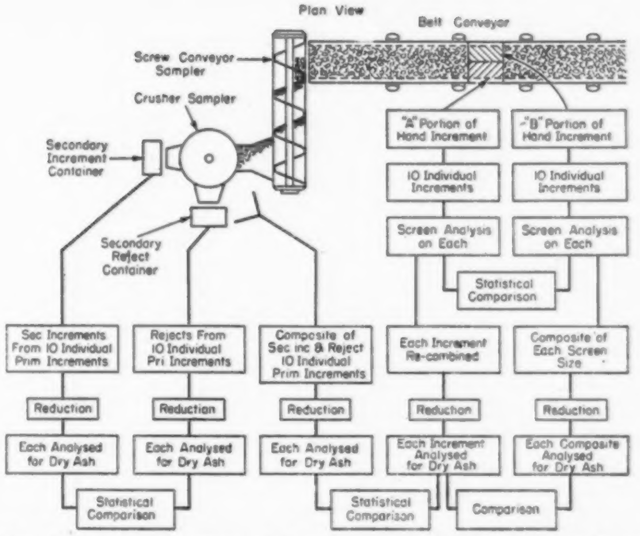

Fig. 2—Determination of the presence of bias was made at the belt conveyor, the screw-conveyor sampler, and the crusher sampler with the individual steps diagrammed above

at the discharge of each of these belts. As shown in Fig. 1 each sampler consists of a motor-driven screw conveyor in a housing installed in the center of the coal stream. A rectangular opening is provided on the top of each screw housing and is so located as to take one-half of the coal stream measuring outward from the mid-point. The sampling opening is normally covered and is exposed to the coal stream only to collect the sample increment (adjusted at present to remain open for 5 sec every $2^1/_2$ min).

The increments (approximately 50 lb each) from these screw-conveyor samplers are delivered through chutes to automatic coal crushers and samplers which crush the coal to 90 per cent passing through a No. 4 sieve and collect a fixed fraction of this coal through the "save" spout. The remainder of the coal or "reject" is discarded to the main coal streams on the belt conveyors.

Upon completion of the sampling of a cargo, the secondary increments from the crushers are mixed by hand, quartered and riffled to give two final samples which are placed in 5-gal can and sealed. This reduction of the gross sample is in accordance with ASTM Method D 492 – 48.

One sample is sent to the laboratory for reduction and analysis in accordance with ASTM Standard Method D 271 – 48; the duplicate sample is retained in reserve by the station.

Tests for Bias

Determination of the presence of bias was made at (1) the belt conveyor, (2) the screw-conveyor sampler, and (3) the crusher sampler. Figure 2 shows diagrammatically the preliminary tests made for such bias.

To check the distribution of the coal on the belt conveyor and the operation of the screw conveyor, ten hand samples or increments were taken from the belt at approximately $^1/_2$-hr intervals during the unloading of a cargo of a single coal and ten samples were taken by the mechanical sampler from the same portions of the coal stream by tripping the mechanical sampler by hand as the hand-cut reached the drop-off point.

The hand samples were taken by stopping the belt and removing a cross-section of the coal by cutting the coal stream with a pair of parallel plates and removing the coal between the plates. A connecting plate, parallel to the coal stream and at the mid-point of the cross-section, divided this sample into two equal parts which were collected separately. The mechanical samples were collected by combining the secondary increment and "reject" from each primary increment at the outlet of the crusher sampler.

The two halves of each hand sample were separately screened through 1-in., $^1/_2$-in. and $^1/_4$-in. square-hole screens. The probability of bias in the distribution of the coal on the belt was studied by a statistical

TABLE I.—SCREEN ANALYSIS OF HAND SAMPLES FROM BELT EXPRESSED AS PER CENT BY WEIGHT

Increment Number	On 1 In.	Through 1 In. on $^1/_2$ In.	Through $^1/_2$ In. on $^1/_4$ In.	Through $^1/_4$ In.	Increment Number	On 1 In.	Through 1 In. on $^1/_2$ In.	Through $^1/_2$ In. on $^1/_4$ In.	Through $^1/_4$ In.
A Portion					B Portion				
1	8.52	20.28	29.14	42.06	1	10.15	19.17	28.68	42.00
2	6.81	24.41	30.13	38.65	2	5.85	17.93	31.81	44.41
3	8.45	21.02	27.48	43.05	3	7.66	20.42	30.55	41.37
4	7.18	19.00	29.28	44.54	4	8.57	16.13	29.72	45.58
5	10.35	26.26	27.52	35.87	5	10.47	21.64	28.79	39.11
6	10.75	23.83	27.06	38.36	6	11.49	23.04	27.39	38.08
7	9.70	21.05	27.00	42.25	7	8.98	22.71	26.76	41.55
8	15.65	25.54	25.18	33.66	8	8.69	21.01	28.33	41.97
9	9.83	23.98	28.30	37.90	9	9.20	20.79	30.32	39.19
10	16.28	20.96	27.73	35.03	10	11.64	20.60	29.62	38.14
Average	10.35	22.63	27.88	39.13	Average	9.27	20.34	29.19	41.14

TABLE II.—TEST FOR BIAS IN SCREW-CONVEYOR SAMPLER ANALYSES OF HAND AND MECHANICAL SAMPLES.

Increment Number	Mechanical Sample, per cent Ash	Hand Sample from Belt, per cent Ash					
		A Portion	*B* Portion				
			Composite of Each Screen Size				Total *B*
			On 1 In.	On ½ In.	On ¼ In.	Through ¼ In.	
1	10.5	9.1	...	...	...	...	...
2	9.8	9.4	...	...	...	...	...
3	9.6	9.9	...	...	...	...	...
4	9.1	10.1	...	...	...	...	...
5	9.8	10.1	...	...	...	...	...
6	10.6	10.2	...	...	...	...	...
7	9.7	9.3	...	...	...	....	...
8	9.7	8.6	...	...	...	...	...
9	9.1	9.0	...	...	...	...	...
10	8.9	8.8	...	...	...	...	...
Average	9.70	9.45	9.70	9.22	8.55	10.30	9.40

analysis of the pairs of screen analyses. The individual increments from the half of the belt corresponding to the location of the sampling gate were then reassembled and separately analyzed for ash content. Each of the mechanically-taken increments was also separately analyzed for ash content. A statistical analysis was then made of the deviation of the hand and mechanical increments. This supplied an estimate of the probability of bias in operation of the primary sampler.

In addition, the screen sizes of the other half of the hand samples were combined and analyzed for ash content. This served as an indication of the variation in ash content with size of coal particles, as well as a check on the similarity of the two halves of the belt.

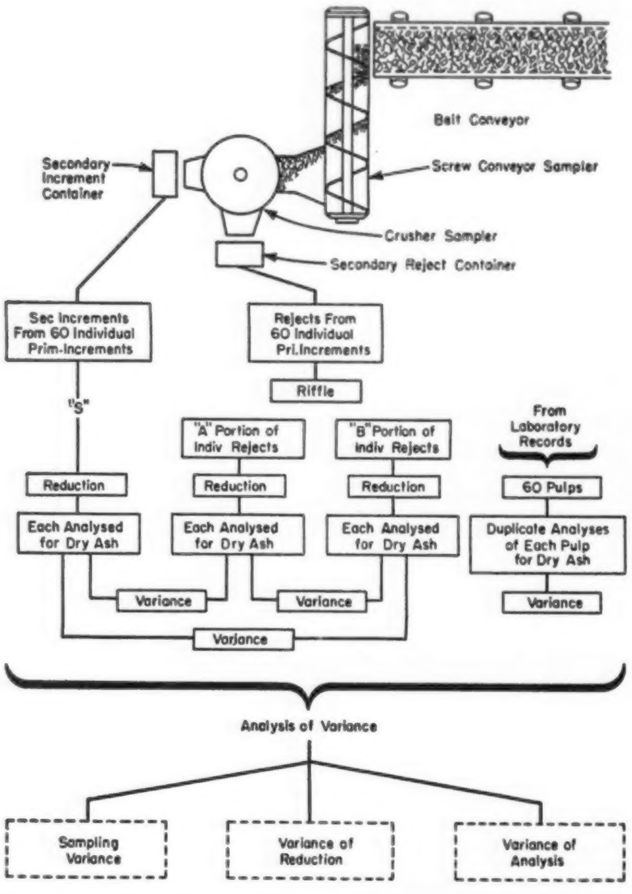

Fig. 3—Actual test procedure outlined above took sample increments from the crusher sampler, with secondary increment and reject from each primary increment collected separately

The next step was to test for bias between the secondary increments and rejects from the crusher. To do this, ten additional primary increments were mechanically collected during the unloading of a cargo. Each of the secondary increments and reject portions was collected separately and individually analyzed for ash content. The probability of bias was determined by a statistical analysis of the deviation of the ash contents of the secondary increments and rejects.

Tables I to III list the basic data obtained from these preliminary samples.

The method used to estimate the probability of bias was the null hypothesis for comparing two sample universes:

$$-t \leq \frac{\bar{d}}{s_d}\sqrt{n} \leq t \tag{1}$$

where:

$\bar{d}$ = average difference between pairs of analyses,
s_d = standard deviation of the difference,
n = number of pairs of analyses, and
t = limiting ratio of actual average difference to standard deviation for $(n - 1)$ degrees of freedom at the probability level desired. This is termed "Student's Ratio," values of which are found in "t Distribution" tables.

If the conditions of Eq. 1 were fulfilled for the probability of 95 out of 100 times, it would be assumed that there was no bias. Conversely, where the probability existed that there was a bias, the magnitude of the difference was considered to evaluate the significance of the condition.

Application of this method to the screen analyses of the hand samples from the conveyor belt gave the following results:

	A Portion	B Portion	$\bar{d}$	s_d	t
Screen Analyses:					
Per cent on 1-in.	10.35	9.27	1.08	2.72	1.25
Per cent through 1-in. on 1/2-in.	22.63	20.34	2.28	2.46	2.92
Per cent through 1/2-in. on 1/4-in.	27.88	29.19	−1.31	1.27	3.35
Per cent through 1/4-in.	39.13	41.14	−2.00	3.13	2.02

Average ash content, per cent by weight	9.45	9.40	...	...	...
Critical value of t for 9 degrees of freedom (10 pairs of samples)	...	...	...	...	2.26

These results show that the small amount of segregation that occurred was too small to have any significant effect on the analysis of the coal.

Applying this method further to the ash analyses of the samples taken by the screw-conveyor sampler and the secondary crusher sampler, the following results were obtained:

	$\bar{d}$	s_d	t
Mechanical sample versus hand sample	0.25	0.723	1.093
Save versus reject of crusher sampler	−0.13	0.206	2.000
Critical value of t for 9 degrees of freedom (10 pairs of samples)	...	...	2.262

This shows that the screw-conveyor sampler was taking a very good sample of the coal passing over it, and the agreement between the secondary increments and rejects from the crusher sampler was within acceptable limits.

Mechanical Coal Sampler Tests

The mechanical coal sampler was tested by extracting one sample increment every 30 min. from the regular sampling of incoming shipments at the East River Station. In this manner, ten sample increments from each cargo were individually crushed and reduced according to ASTM procedures. For the purpose of this study, each cargo was considered a sublot. This

TABLE III.—TEST FOR BIAS IN CRUSHER-SAMPLER ANALYSES OF SECONDARY INCREMENTS AND REJECTS FROM CRUSHER.

Increment Number	Weight, kg: Secondary Increment	Weight, kg: Reject	Per Cent Ash: Secondary Increment	Per Cent Ash: Reject	Screen Analysis of Secondary Increment, per cent on No. 4 sieve
1	3.060	19.395	9.9	9.7	10.1
2	3.100	20.070	9.6	9.7	11.7
3	2.430	22.335	9.6	9.6	9.1
4	4.480	25.280	9.9	9.8	7.8
5	2.810	18.195	9.4	9.4	6.3
6	3.840	24.625	9.6	9.8	9.1
7	4.300	24.460	9.7	10.1	8.8
8	4.270	24.140	9.8	10.0	8.2
9	3.480	21.255	10.0	10.4	11.8
10	3.545	21.590	9.7	10.0	9.3

experimental sampling was continued over six coal cargos, totaling 13,600 tons, which were considered to represent one lot of coal.

The test program followed in this experimental sampling is shown diagrammatically in Fig. 3. The sample increments were taken at the outlet of the crusher sampler. The secondary increment and reject from each primary increment were collected separately, and in addition each reject portion was riffled once to produce two separate samples from each reject. All of these were individually reduced and analyzed for ash. To prevent any possible bias in the riffle, the collecting pans were interchanged after half the increment had been put through the riffle. Table IV gives the results of these analyses.

The calculation of the variability due to random errors in the laboratory analyses was made from 60 duplicate analyses made as a routine check on laboratory technique. These analyses are shown in Table V.

TABLE IV.—RESULTS OF COAL SAMPLING TEST AT EAST RIVER STATION.

Sublot 1—2208 Net Tons Coal from 2 Sources

Primary Increment No.	Per Cent Ash: Secondary Increment	Per Cent Ash: Reject A	Per Cent Ash: Reject B	Weight, kg: Secondary Increment	Weight, kg: Reject A	Weight, kg: Reject B
1	8.7	8.6	8.6	4.35	12.61	13.18
2	8.6	8.8	8.8	4.42	14.69	14.08
3	9.1	9.3	9.1	3.84	13.91	12.41
4	8.5	9.3	9.5	4.45	13.92	13.30
5	8.7	8.8	9.2	4.55	13.34	14.94
6	9.3	8.7	8.9	4.27	13.97	12.40
7	8.8	8.5	8.9	3.88	11.63	12.92
8	9.4	9.3	9.6	4.67	12.12	13.92
9	10.0	9.5	10.1	3.72	12.03	11.33
10	8.6	8.6	7.9	4.53	14.77	13.52
Totals	89.7	89.4	90.6	42.68	132.99	132.00
Average	8.97	8.94	9.00			

Sublot 2—2303 Net Tons Coal from 2 Sources

Primary Increment No.	Per Cent Ash: Secondary Increment	Per Cent Ash: Reject A	Per Cent Ash: Reject B	Weight, kg: Secondary Increment	Weight, kg: Reject A	Weight, kg: Reject B
11	8.9	8.9	9.2	2.89	10.09	9.61
12	10.1	9.4	8.8	3.67	11.39	13.13
13	8.6	8.6	7.9	2.33	8.54	8.61
14	8.8	7.7	8.3	2.28	7.95	8.88
15	10.1	8.3	9.7	2.88	10.74	11.36
16	9.2	8.8	8.5	2.59	9.99	10.79
17	10.6	9.8	9.3	2.20	7.72	7.51
18	10.6	10.1	9.8	2.15	8.47	8.07
19	9.4	9.7	10.3	2.41	8.68	10.72
20	9.9	8.7	9.5	2.81	11.21	9.68
Totals	96.1	90.0	91.3	26.21	94.78	98.36
Average	9.61	9.00	9.13			

Sublot 3—2285 Net Tons Coal from 2 Sources

Primary Increment No.	Per Cent Ash: Secondary Increment	Per Cent Ash: Reject A	Per Cent Ash: Reject B	Weight, kg: Secondary Increment	Weight, kg: Reject A	Weight, kg: Reject B
21	10.9	11.0	10.6	2.78	8.66	9.25
22	11.2	10.7	10.5	3.81	12.46	13.05
23	10.3	10.1	10.0	3.90	12.58	12.69
24	9.4	9.6	10.2	3.84	12.77	11.84
25	10.8	10.7	10.3	2.97	9.59	10.28
26	9.7	9.8	9.9	3.39	11.91	10.92
27	9.9	9.5	9.7	3.53	12.50	12.17
28	8.9	8.4	8.2	4.51	13.60	13.95
29	8.5	8.6	8.2	2.49	11.25	10.20
30	10.0	9.5	9.5	2.44	11.38	9.34
Totals	99.6	97.9	97.1	33.66	116.65	113.69
Average	9.96	9.79	9.71			

Sublot 4—2299 Net Tons Coal from 2 Sources

Primary Increment No.	Per Cent Ash: Secondary Increment	Per Cent Ash: Reject A	Per Cent Ash: Reject B	Weight, kg: Secondary Increment	Weight, kg: Reject A	Weight, kg: Reject B
31	10.8	10.0	9.9	2.38	8.93	8.78
32	9.6	10.1	9.9	2.32	8.47	8.90
33	7.8	7.6	7.4	1.77	6.98	7.17
34	8.5	8.6	8.5	1.98	7.97	7.75
35	8.3	8.1	8.2	1.99	7.89	7.39
36	9.3	9.3	9.0	2.27	9.20	9.70
37	8.2	9.2	8.7	3.00	9.45	9.41
38	9.9	9.3	9.4	3.63	12.01	12.35
39	9.2	8.6	9.0	2.34	7.93	7.03
40	9.6	9.5	9.3	3.26	10.22	10.25
Totals	91.2	90.3	89.3	24.94	89.05	88.73
Average	9.12	9.03	8.93			

Sublot 5—2235 Net Tons Coal from 3 Sources

Primary Increment No.	Per Cent Ash: Secondary Increment	Per Cent Ash: Reject A	Per Cent Ash: Reject B	Weight, kg: Secondary Increment	Weight, kg: Reject A	Weight, kg: Reject B
41	10.7	10.7	9.7	3.90	12.24	12.30
42	10.7	10.0	10.5	2.20	8.60	7.90
43	9.2	9.4	9.5	3.13	11.25	11.02
44	9.0	9.1	8.9	2.93	9.87	10.01
45	9.0	8.8	9.1	2.97	10.08	9.87
46	8.9	8.4	8.9	3.42	11.03	12.32
47	9.6	8.5	8.8	3.45	11.09	11.22
48	11.7	10.3	10.9	2.34	9.96	9.93
49	10.4	9.5	9.4	3.12	10.52	10.68
50	11.6	10.4	9.6	3.75	12.06	12.20
Totals	100.8	95.1	95.3	31.21	106.70	107.45
Average	10.08	9.51	9.53			

Sublot 6—2299 Net Tons Coal from 2 Sources

Primary Increment No.	Per Cent Ash: Secondary Increment	Per Cent Ash: Reject A	Per Cent Ash: Reject B	Weight, kg: Secondary Increment	Weight, kg: Reject A	Weight, kg: Reject B
51	9.3	9.0	9.7	2.84	12.06	12.29
52	9.7	8.9	9.1	2.56	10.86	10.43
53	9.6	9.0	8.8	2.56	9.61	9.20
54	9.4	9.4	8.7	2.53	9.98	10.39
55	9.3	8.7	8.8	2.13	8.51	8.77
56	9.6	9.9	9.1	2.96	12.06	11.63
57	8.9	8.8	9.5	2.82	12.38	12.02
58	8.6	8.7	8.3	2.32	9.91	10.42
59	9.4	9.3	9.2	3.19	12.47	13.38
60	9.3	8.8	8.9	2.71	11.60	10.90
Totals	93.1	90.5	90.1	26.62	109.44	109.43
Average	9.31	9.05	9.01			
Grand Total	570.5	553.2	553.7	185.32	649.61	649.66
Cumulative Average	9.51	9.22	9.23			

TABLE V.—DUPLICATE ANALYSES OF LABORATORY PULP

	Ash, per cent			Ash, per cent			Ash, per cent			Ash, per cent	
	Original Analysis	Second Analysis		Original Analysis	Second Analysis		Original Analysis	Second Analysis		Original Analysis	Second Analysis
No. 1..	8.3	8.7	No. 16..	8.2	8.2	No. 31..	10.3	10.4	No. 46..	9.2	9.2
No. 2..	10.6	10.4	No. 17..	8.3	8.1	No. 32..	9.7	9.5	No. 47..	10.6	10.1
No. 3..	10.3	10.2	No. 18..	8.6	8.8	No. 33..	12.0	12.2	No. 48..	7.6	7.9
No. 4..	8.7	8.7	No. 19..	6.9	7.1	No. 34..	10.8	11.1	No. 49..	8.6	8.8
No. 5..	8.5	8.7	No. 20..	9.1	9.5	No. 35..	10.1	10.0	No. 50..	8.8	9.0
No. 6..	9.2	9.2	No. 21..	12.1	12.1	No. 36..	10.3	10.5	No. 51..	8.4	8.3
No. 7..	9.7	9.4	No. 22..	7.0	6.7	No. 37..	7.1	7.3	No. 52..	11.5	11.4
No. 8..	9.3	9.4	No. 23..	9.0	9.3	No. 38..	9.7	9.7	No. 53..	10.3	10.4
No. 9..	7.8	7.5	No. 24..	12.8	13.1	No. 39..	10.4	10.7	No. 54..	12.1	12.2
No. 10..	9.9	10.0	No. 25..	8.4	8.3	No. 40..	9.7	10.0	No. 55..	9.5	9.3
No. 11..	11.0	10.9	No. 26..	9.1	8.9	No. 41..	10.0	10.2	No. 56..	7.7	7.6
No. 12..	10.3	10.1	No. 27..	8.3	8.3	No. 42..	8.7	8.6	No. 57..	8.9	8.9
No. 13..	11.7	11.4	No. 28..	10.3	10.4	No. 43..	9.4	9.4	No. 58..	8.1	7.9
No. 14..	11.7	11.9	No. 29..	11.45	11.76	No. 44..	9.9	9.7	No. 59..	9.7	9.5
No. 15..	3.9	3.8	No. 30..	7.7	7.7	No. 45..	9.4	9.4	No. 60..	9.5	9.6

The relationship of the variances involved has been expressed by Bertholf as:

$$s_o^2 = s_t^2 + s_i^{2/w} + s_r^2 + s_a^2 \qquad (2)$$

where:

s_o^2 = observed variance,
s_t^2 = trend variance,
s_i^2 = variance of the increment of unit weight,
w = weight of increment,
s_r^2 = variance of reduction, and
s_a^2 = variance of analysis.

The number of increments required per gross sample is expressed by:

$$N = \frac{s_t^2 + s_r^{2/w}}{Ls_s^2 - \left[\frac{s_r^2 + s_a^{2/k}}{p}\right]} \qquad (3)$$

where:

N = number of increments required per gross sample,
s_s^2 = specified variance for required accuracy in reported average of the lot,
L = number of gross samples per lot,
p = number of pulps per gross sample, and
k = number of analyses per pulp.

The variances of the individual steps of the sampling operation were found to be as follows:

Variance of sampling......	$(s_t^2 + s_i^{2/w})$	= 0.393
Variance of reduction......	(s_r^2)	= 0.154
Variance of analysis.......	(s_a^2)	= 0.022

These figures show that the sampling variance of a single increment is about twice as much as the variance of the subsequent reduction and analysis. Combining a number of increments into one sample for analysis reduces this variance of sampling. In this manner, the sampling variance can be made very small and the variance of reduction and analysis will then be the controlling factor in the overall accuracy of the operation. This error of reduction and analysis can be reduced by taking a larger number of gross samples per lot, by reducing a number of pulps from each gross sample, or by improving the technique.

The accuracy of the East River Station mechanical sampler under these conditions compares with ASTM requirements as follows:

	Limit of Error* of Ash Content, per cent of Coal, 95 per cent of Time	
	For Each of Six Cargos	Considering Six Cargos as One Lot
Test samples: 10 increments per cargo (individually analyzed increments).....	±0.48	±0.20
Station sample: one gross sample per cargo.........	±0.89	±0.36
ASTM tolerance: 9.5 per cent ash coal............	±0.95	±0.95

* Approximately twice the standard deviation.

When coals similar to those received at this station are mechanically sampled and analyzed by present procedures, these test results show that the conditions in Table VI prevail.

As indicated above, calculations show that for these coals it is impossible to achieve an accuracy of ±5 per cent of the ash content with a single gross sample.

Earlier Sampling Investigations

Of the large number of coal sampling tests conducted over the last 20 years, three are particularly relevant

TABLE VI.—COAL SAMPLE INCREMENT REQUIREMENTS

	For Commercial Purposes, ±10 per cent of Ash Content			For Special Purposes, ±5 per cent of Ash Content	
	Indicated by Test Results	Required by ASTM		Indicated by Test Results	Required by ASTM
Size of lot, tons..........................	13 600[a]	1000	Over 1000	13 600[a]	1000
Number of gross samples.................	1	1	1	4	1
Total number of increments..............	11	35	140	44	140
Weight of increments, lb..................	55	6	6	55	6

[a] Actual size of lot tested, including coal from ten sources. No mathematical limit to lot size.

to the East River Station mechanical sampler tests. Initially, Morrow and Proctor (4) established the variables in coal sampling by extensive tests on raw coal at the mine. The results of these tests constituted the basis for the present ASTM Method D 492. Subsequently Landry and Anderson (1) made sampling tests to provide fundamental data for design of any coal sampling system. Finally, American Gas and Electric Service Corp. (5) made very elaborate tests with a Geary-Jennings mechanical sampler at the Cabin Creek Plant.

Basic data from these three tests have been analyzed, and the following results have been obtained using Bertholf's (2, 6) methods:

Kind of Coal	Average Ash Content, per cent	Size of Increments, lb	Number of Increments Tested	Sampling variance
$1^1/_8$-in. Pittsburgh raw slack	10.7	8	50	2.091
Enos	12.6	40	30	1.083
Cabin Creek 2 by 0 in.	10.1	40	79	0.884
East River Station mixed coals	9.5	55	60	0.393

These figures reflect the uniformity of the respective coals sampled, the Pittsburgh raw slack being the least uniform. They show that to obtain any specified accuracy a greater number of increments must be taken of the less uniform coals. They also show that mixed coals such as are currently received at East River Station, with the extensive crushing and mixing carried out prior to sampling, are much more uniform than had been heretofore thought.

Conclusions

From these tests on the East River mechanical coal sampler, it is concluded that for the coals currently used:

1. The ASTM limitation of the size of a lot of coal for sampling purposes to only 1000 tons is not justified inasmuch as lots as large as 13,000 tons gave satisfactory accuracies for "commercial sampling." This accuracy depends on the variability of the coal as well as on each step in the sampling and the analysis.
2. The number of increments of 50 lb each required for the 1000-ton lot by the ASTM commercial sampling procedure is adequate for the 13,000-ton lot. However the "special purpose" accuracy of ±5 per cent of the ash content can be obtained in any case with a single gross sample.
3. The accuracy of ±5 per cent of the ash content can be obtained only by increasing the precision of the sampling and reduction operations or by taking and analyzing several gross samples separately as provided by the ASTM method.

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Relation of Coal to Atomic Energy

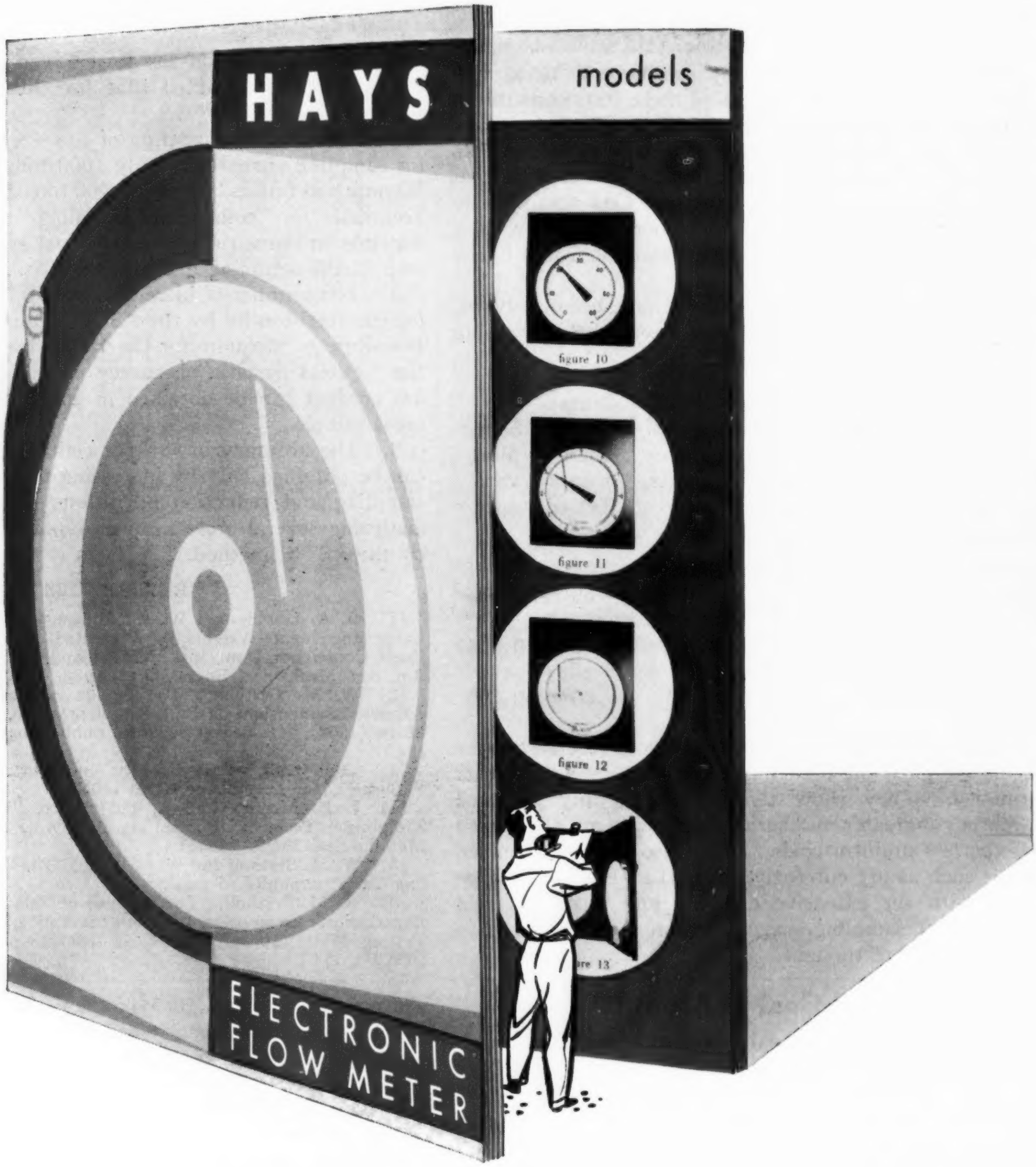
Addressing the 1954 Coal Convention of the American Mining Congress in Cincinnati, Ohio, on May 4, Walker L. Cisler, president of The Detroit Edison Co., stated that the need for coal for power generation will continue at increasing levels for many years to come even if the use of atomic energy becomes feasible for central stations. He expressed the belief that, from the standpoint of electric power, adverse effects of atomic fuels on the coal industry appear far in the future and very likely may be offset by future changes in the energy situation.

Atomic energy must be regarded as another national resource. Despite its horror when employed as a weapon of war, we cannot legislate against its development. Instead, we must develop it for peaceful purposes. If this can be done, it will entegrate and sustain our economy, conserve other resources and improve our standard of living, he added.

Mr. Cisler cited AEC estimates that the known world supply of recoverable uranium and thorium is 27,000,000 tons and represents 23 times the amount of energy available from all known oil and gas reserves in the world. Because present fossil fuel resources will eventually be depleted, there is no question about the advisability of pushing the development of atomic fuels.

Forecasts based on increasing power demands indicated that present demands for coal for power generation will continue to increase. By 1965 the nation's total thermal electric generating capacity will have risen from the present 69 million kw to a predicted value between 150 and 175 million kw. Thus by 1965 the nation's power plants may be using as much or more than 250 million tons of coal annually as compared to the present 116 million tons.

Mr. Cisler also pointed out that coal occupies a position with respect to oil and gas that is similar to that between atomic fuels and eoal. In other words, when gas and oil reserves begin to dwindle, coal may be an economical source for synthetic fuels.



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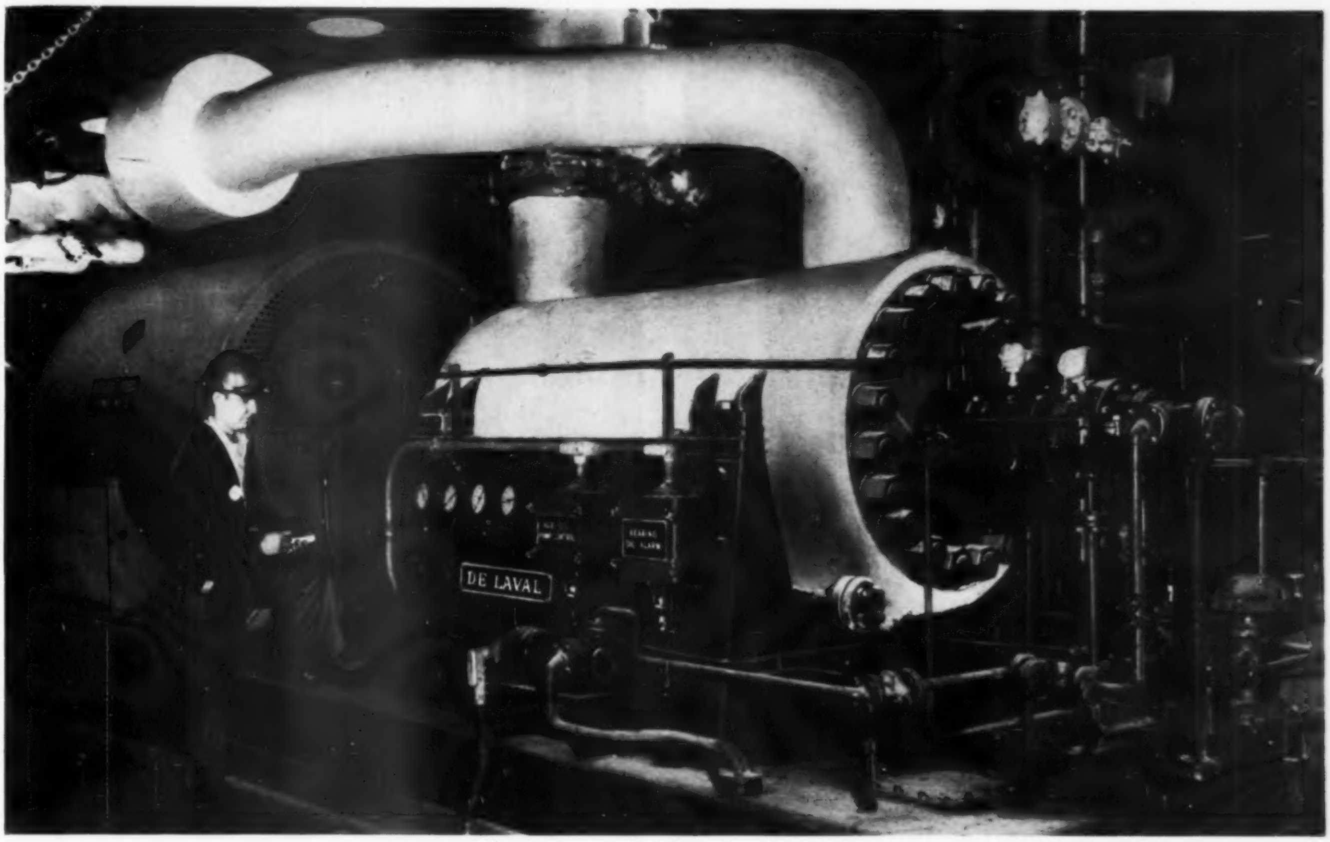


Planning Systematic Pump Replacements

All too often the only time new pumps come into a power plant is when the basic steam cycle has been changed. Yet there are many times when the "old reliables" could be replaced profitably by new pumps with new design advantages. Here are some helpful check points to aid in evaluating existing equipment.

By C. E. CROMWELL
De Laval Steam Turbine Co.

ORDINARY wear and tear on the moving parts of boiler feed pumps, condensate pumps, circulating water pumps or raw water supply pumps takes place so gradually and over so long a period that the price it exacts in lowered operating efficiency mounts up unnoticed.

For example, a pump may still be delivering designed capacity and head despite its age. Because of this seemingly satisfactory performance, the pump protects its reputation as an "old faithful." Its gradual decreasing efficiency is not as noticeable as if it were to suffer a sudden breakdown. What's more, its power costs seem reasonable and will be accepted as such unless they are totaled up over a number of years and compared with similar costs for a new pump.

Take a pump that is twenty or thirty years old. The standard operating costs of power, repairs and depreciation hold. If two out of the three—power and repairs—run considerably higher than a modern replacement, it's good operation to know. Pump manufacturers have come a long way in designing units to reduce overall operating costs.

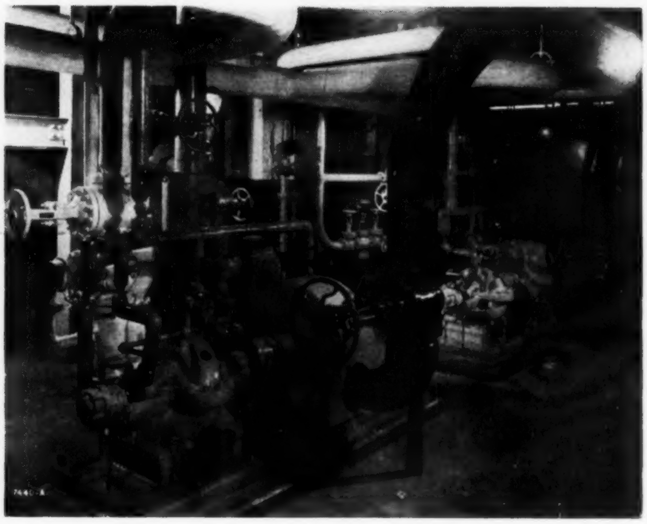
Consider a motor-driven boiler feed pump built in 1928 to handle 2500 gpm against a 150 ft head. When originally built it had an efficiency of 78 per cent requiring an input of 121 bhp. Due to wear and tear and with no revolving parts replaced, the pump's efficiency by 1954 would have slipped off some four per cent to about 74 per cent, requiring 128 bhp to deliver the designed capacity and head.

A modern pump for these same conditions could be expected to have an efficiency of 86 per cent, requiring 110 bhp or a possible saving of 18 bhp. Based on a power cost of one cent per kwhr, savings in power costs for one year's operation (8760 hr) is $1176.

The cost of a new pump or complete unit and the time it would take to pay for it from the operating savings gained over the old pump can be compared in table form below. The figures in this table were drawn up with a base of one cent per kwhr, or $0.00746 per hp. To make these comparison figures practical, freightage, foundation and piping charges should be added to the total cost figure.

Price (estimated) of new pump, base, coupling	$1238
Price (estimated) of 125-hp, 440-V, 1750-rpm motor..............................	$1390

Maintenance on a regularly scheduled basis will keep pump performance close to the design levels for many years



New pumps with compact assemblies permit orderly pump room layouts with proper piping clearances, yet save space

Price (estimated) of reduced voltage starter..	$1170
Total cost of new pump, motor, starter......	$3798

So much for the cash outlay. How about the payoff period?

Hours per year of operation.....	8760	6500	4000
Required time, months, for savings to pay for pump, base, etc.	13	17	28
Required time, months, for savings to pay for complete unit..	39	52	84

The only alternative, to put in renewal parts for worn out ones, will result in restoring the pump to its original 78 per cent efficiency. This means 121 bhp of power input as against a 1954 pump design requirement of 110 bhp. If the pump runs an 8760-hr operating year, this 11 bhp difference produces a power cost at one cent per kwhr of $719 more for the revamped 1928 model as against the 1954 unit. Over and above this consideration is the one of obsolescence. There is a strong likelihood as the pump grows older that its replacement parts will become relatively expensive compared with the cost of a modern pump.

If the amount saved each year on power cost were set aside to accumulate interest, the total would soon represent an amount that would pay for all or part of the cost of a new unit, Table I. Where a company employs relatively long term write-offs, these accumulated savings could pay for the unit and supply cash for other capital expenditures.

Pump Tests

Acceptance tests are the usual order of business when new equipment goes into service. Similar tests run periodically on long-operating equipment could prove equally illuminating. A recent report[1] outlined the general requirements and some of the limitations for acceptance tests of the major power-plant equipment including pumps. Its suggestions on pump tests in compiling data to evaluate pump replacement could be summarized as follows:

In testing the performance of pumps the usual practice involves comparing operating heads and efficiencies with the expected values for various flow rates. The efficiency of the pump can be calculated from the ratio of the water horsepower to the shaft horsepower. The water horsepower, in turn, is determined from the measured fluid flow rate and total head developed. The shaft horsepower results from calculations involving the measured power input to the motor after taking into account the motor and coupling (if any) efficiencies. If turbine drives are used, the steam flow to the turbine and the inlet and outlet enthalpy of steam must be measured.

To determine pump performance measure the following items:

1. Flow rate of fluid leaving the pump.
2. Discharge head.
3. Suction head.
4. Speed of pumps and motors.
5. Power input to pumps.
6. Temperature of fluid entering the pump.

In determining the test total head (which is the difference between discharge and suction heads) it is necessary to add velocity head to suction head. But in the case of high head pumps such as boiler feed pumps and condensate pumps the velocity is negligible. For low head pumps such as circulating water pumps the velocity head becomes important.

With variable speed operation the test head and capacity must be corrected to the design speed basis for comparison purposes. Similarly, the pump speed for this class operation is necessary to determine coupling efficiencies. The coupling efficiency (excluding small fixed losses) is directly proportional to slip.

Power input to motors driving pumps is generally determined by a portable wattmeter or watt-hour meter. Occasionally power input is calculated by taking the voltage, amperage and power factor readings.

With a set of comparison figures such as above, the relative performance of an old pump can be definitely established against its original design capabilities, as well as against a similar set of figures for a modern pump of the same rating.

[1] "The Effect of Measurement Errors on Plant Performance Tests," by Dr. S. Baron, Head, Heat Balance Dept., Burns and Roe, Inc., COMBUSTION, February 1954.

Write-Off Advantages

A municipality figures in terms of 15 years or more and at interest rates of possibly 3 per cent. A small annual saving, based on the preceding example, soon pays for the original investment. In fact, many cases show that by the end of a 15-year term such savings would represent the write-off of a much larger capital expenditure. Take the $1176 saved on power cost with a new pump, as shown in the sample case above. If for a municipality this amount were set aside to accumulate interest at 3 per cent compounded annually for 15 years, a capital investment of $21,871 would be written off, Table I.

Some operators of central-station power plants believe that in a new station a unit that pays for itself in 8 to 10 years is a good investment. When replacing old equipment, the expected life of the plant may reduce the length of write-off that can be considered. This premise must be considered throughout industry, regardless of the products.

Chemical companies or refineries prefer to write off investments in 3 to 4 years, or possibly 2 years. A chemical company capitalizing the savings at 4 per cent for 4 years could write off an investment of $4994.00.

Calculating Savings

Calculation of power cost savings and capitalization amounts can be made quickly by using the following chart. First compute the horsepower savings and multiply the results by yearly hours of operation. This chart can be used for quick approximations and can be read within about 2 per cent accuracy.

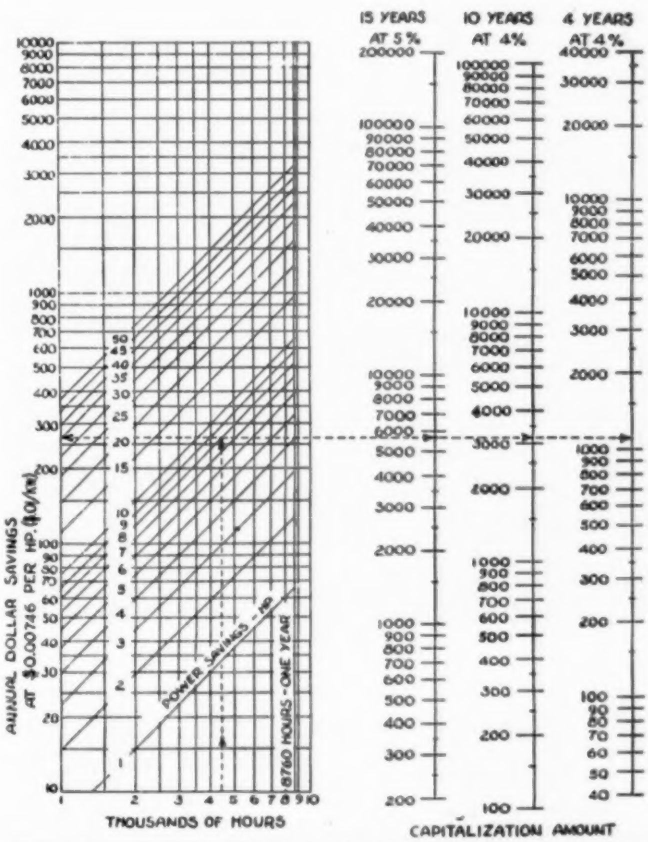


Chart form permits quick check-off of allowable capitalization against major controlling factors

The diagonal lines represent "horsepower savings." The abscissa shows "hours per year" of operation. Reading vertically up the "hours per year" to the "horsepower savings," to the left ordinate is the "annual savings" in power cost, and to the right ordinate is the "capitalization amount." Shown are three right-hand ordinates, each for different interest rates and terms of years.

The chart is based on cost of power at $0.01 per kw. If in a particular locality power cost is more or less, simply multiply answer from the chart by the ratio to actual cost; i.e., if the cost is 12 mills per kw, multiply by 1.2; if the cost is 9 mills per kw, multiply by 0.9.

The following examples are taken from records to show what improvements in efficiency have been made and the savings and capitalization amounts are taken from the attached chart.

Examples

1. Service Water Pump. Consider a pump installed in 1926 having an efficiency of 70 per cent and an input of 28.9 bhp. A modern pump for the same conditions (400 gpm, 200 ft total head) has an efficiency of 79 per cent and an input of 25.6 bhp. This is a 3.3 bhp saving. Annual saving if service water pump runs 6000 hours per year is $150. Capitalized in 4 years at 4 per cent interest the total amount is $630. The estimated price of a new pump for these operating conditions is $438.
2. Boiler Feed Pump. 40G gpm, 650 total head at 220 F.

   Year 1930, efficiency 63%, 99.5 bhp
   Year 1953, efficiency 69%, 91.0 bhp

   8.5 bhp saving

Annual saving if pump operated 8760 hours per year is $560. Annual savings capitalized in 10 years at 4 per cent represents a total of $6700. Estimated cost of new pump is $1101.

3. Water Works Pump. 15 mgd (10,400 gpm), total head-200 ft

   Year 1926, efficiency 84%, 625 bhp
   Year 1953, efficiency 89%, 590 bhp

   35 bhp saving

Annual saving if pump operated 5000 hours per year is $1300. Annual savings capitalized in 15 years at 3 per cent represents a total of $24,177. Estimated price of new pump is $4054.

When accurate calculations are required for formal

TABLE I.—CONVERSION FACTORS FOR ANNUAL SAVINGS UNDER FIXED INTEREST, COMPOUNDED

Years	% Interest Rate/Annum, Compounded Annually 2	3	4	5	6
2	0.49505	0.49261	0.49020	0.48780	0.48544
3	0.32675	0 32353	0.32035	0.31721	0.31411
4	0.24262	0.23903	0.23549	0.23201	0.22859
6	0.15853	0.15460	0.15076	0.14702	0.14336
8	0 11651	0.11246	0.10853	0.10472	0.10104
10	0.09133	0.08723	0 08329	0.07950	0.07587
12	0.07456	0.07046	0.06655	0.06283	0.05928
15	0.06260	0.05377	0.04994	0.04634	0.04296

Annual power cost savings, such as $1176 cited in article example, divided by factors in table above, equals sum that will accrue if savings and interest accumulate for a number of years at interest rates indicated

presentation, annual savings are obtained by multiplying horsepower savings by yearly hours of operation × cost per horsepower hour (kwhr cost × 0.746). The annual savings divided by a factor, based on terms of years of interest rate, will give the capitalization amount. Table I lists these factors for various terms and interest rates. These can also be used for terms other than those shown on the chart.

Undoubtedly, plant engineers in industry and municipalities realize that the hidden costs of operating old equipment could very well represent the purchase price of new equipment. But management officials must be shown why the purchase of modern equipment is a wiser investment than the continuing costs of operating old equipment. In some cases the actual cost factors of operating old equipment are obscured because power costs are negligible, where power is obtained as the by-product of process, or the unit may be depreciated.

If power and depreciation are negligible factors, which is seldom the case, there are still repair costs of some kind to consider. Obsolete parts are more expensive and require extended delivery time. Should production losses occur because of the delay in obtaining obsolete renewal parts, the losses are chargeable to the old pump. The cost of modern renewal parts for which patterns are available and the parts are in stock represent very tangible savings when compared with the cost of obsolete parts. Sometimes a modern pump can be purchased at prices equal to or even less than the cost of extensive renewal parts for an old pump.

Continuous Mining Machine

A newly developed continuous mining machine, the invention of which is credited to K. L. Konnerth, vice president in charge of coal operations for the United States Steel Corp., is now in service in several mines of that organization. Vibratory force is applied to the coal face through two electric hammers mounted on a telescopic carriage. Hydraulically operated cylinders raise and lower the hammer carriage to a maximum of 80 in., extend and retract the hammers to a maximum of 34 in. and swing the carriage turntable to the right or left within the limits of the shear bars. Through these limits the vibrating hammers can be utilized to trim roof and break down coal at the face.

The hammer is a cylinder upon which two electromagnets are assembled. The piston or core is free to slide back and forth between two bearings positioned one at each end inside the cylinder. The stroke is established by a core stop at the back end of the cylinder and a vibrating tool shank at the other end. A preloaded coil spring holds the core stop in position and absorbs the piston's return-stroke energy. Another preloaded coil spring is set against a spring seat on the tool end and serves to limit the stroke when the vibrating tool is operating in free air.

Actuation of the piston is by means of a pulsating direct current, which provides a resultant cyclic speed of 1800 blows per minute. Strain gage measurements have indicated that each blow exerts a force of about 30,000 lb.

The machine, which weighs 46,000 lb, is powered by a d-c motor. All operations such as cutting, tramming and conveying are performed mechanically and are controlled through hydraulically operated disc clutches.

Test of Ceramic-Coated Air Heater Tubes

A SIX months' test under actual operating conditions and involving 4000 hr of continuous service has proved that ceramic-coated steel tubes can reduce operating costs and maintenance problems of air preheater tubes in power plants.

Conducted by John P. Gallagher, director of utilities for the municipal power plant in Piqua, Ohio, the tests covered 107 out of a total of 749 tubes in actual operation at the plant. The tubes were installed in the air preheater section of a Combustion Engineering boiler using counter flow air preheaters. Each tube was 13 ft long, composed of three sections, each 52 in. long. Mr. Gallagher developed this design for the test. In normal operation, the tube would be continuous. Each tube was $2^1/_2$ in. O.D. × 0.083 in. wall. Joints were ERW steel sleeves $2^1/_2$ in. I.D. × 0.083 in. wall six inches long with a circumferential "V" groove.

The fuel burned in this boiler was Ohio strip coal, generally the first or second cut with a sulfur content ranging from 3 to 8 per cent and a heating value of 10,800 Btu. Gas temperature at inlet was approximately 450 F and 350 F at the outlet. Air temperature was 100 F at inlet and 250 F at the outlet.

New tubes were installed throughout the boiler section with plain steel tubes in the upper hot zone and middle sections: ceramic coated tubes were installed in the lower cold-zone sections of the first row. This arrangement was selected in order to subject the coated tubes to the coldest air flow with greatest exposure to condensates. These Vitralloy tubes are produced by Barrows Porcelain Enamel Company, of Cincinnati, who had subjected such tubes to exhaustive laboratory analysis but wished to determine actual operating experience.

From August 1953 until March 27, 1954, the air preheater was operated continuously without cleaing. On April 1, 1954, two tubes of three sections each were removed from the air preheater. They were completely filled with fly ash from end to end. After tamping the ends of each section on the floor, the bulk of the fly ash was loosened and fell out. However, a white crust, $^1/_8$ to $^1/_4$ in. thick, was formed in a film on the inside of the plain steel tubes. The fly ash adhered to this. No white crust was observed in the Vitralloy tubes and only a thin layer of fly ash adhered to the inner surfaces.

For a closer examination of the interior walls, portions were sawed from each tube then re-sawed lengthwise in half. The film of ash remaining on the Vitralloy surfaces was easily removed by rubbing with a bare finger. This exposed the original surface of the vitreous coating. Some of the remaining fly ash in the plain steel tubes could be rubbed off in the same manner but the white crust was compacted and adhered tightly to the steel.

Since this white crust was apparently the focal point of the test and caused a major restriction in the tubes, it was subjected to a chemical analysis. The analysis, by weight, was as follows:

Ferrous sulfate	82.00%
Manganese sulfate	0.3 %
Sulfuric acid	3.43%
Moisture	11.8 %
Undetermined	2.5 %
Total	100.03%

The formation of the ferrous sulfate was the result of the sulfuric acid combining with the steel of the tubes. A marked sulfurous odor was noted from the ferrous sulfate scale.

To learn if this white crust could be dissolved, each of the cross-sections was successively immersed in plain hot water ranging from 180 to 200 F held in a galvanized iron bucket. Each section remained under water about five minutes. Each was moved up and down prior to removal from the bucket. This provided a rinsing action but no attempt was made to scour the sections. Most of the gray ash disappeared from the plain steel tubes but no change could be observed in the ferrous sulfate scale.

While the tubes were immersed in the water, a steady stream of bubbles emerged at the surface around the inner circumference of the bucket. After the tests were completed, the bucket was emptied. Its inner surface appeared black below the water line. This would indicate that a highly active sulfuric acid residue remains in the ferrous sulfate scale and attacked the zinc coating of the bucket.

The scale on the plain steel tubes remained intact; it resisted removal even when scraped with a steel screw driver. After continued efforts, the scale was finally removed. Close inspection revealed pitting of the steel surface indicating an active attack on the metal by the scale.

The sooty residue remaining on the Vitralloy tubes was analyzed and found to be as follows:

Ferric sulfate	31.65%
Free sulfuric acid	22.55%
Carbon	8.00%
Moisture	15.23%
Ferrous iron	0.39%
Ash other than iron compound	22.50%
Total	100.32%

The ash other than the iron compound consisted of silica, alumina, lime and magnesia—the normal constituents of coal ash. This deposit is a mixture of sulfuric acid and fly ash containing some unburned carbon. The sulfuric acid has reacted to some extent with the fly ash forming ferric sulfate. The absence of significant amounts of ferrous iron is a good indication that the corrosion of steel or iron is not the source of the iron compounds.

No residue was apparent on the surfaces of the Vitralloy tubes after the hot water immersion test. Except for slight corrosion at the extreme outer edge, a continuous unbroken vitreous appearance was presented. The corrosion occurred at the edge of the tube engaged inside the plain steel sleeve used to join the lower tube to the middle tube.

The minor corrosion and penetration at the end of the coated tube engaged in the sleeve joint was apparently caused by initial corrosion starting in the unprotected sleeve wall. A special acid-resistant glass, developed after the test's start, is now applied as a standard coating on these tubes and is also recommended for sleeve protection. This would prevent corrosion in similar assemblies and joints. It is logical, however, to say that a continuous one-piece tubing is far superior.

From the inspection and analysis of these tubes, it was determined that two primary problems exist in air preheater use. These are clogging and corrosion.

Clogging is present in three phases: a finely powdered dry fly ash, a cohesive powdered ash, and a ferrous sulfate scale. All three were present in the plain steel tubes while only the first two types were present in the vitreous enamel coated tubes. The absence of the third type is regarded as evidence that the steel is protected by the borosilicate glass fused to the base metal.

Clogging and corrosion started at the cold end and progressed to approximately the midpoint of the heater. It seems apparent that, in spite of the relatively high flue-gas exit temperatures and closely controlled inlet air temperatures used in this installation, this clogging and corrosion progressed to a point well above the normally considered cold zone. A conclusion drawn from this is that Vitralloy tubes would prove beneficial if used throughout the air heater.

While in this installation, due to construction, the tubes were uncleaned during the six months' period, periodic cleaning should be regular procedure in normal power plant operation. Since the ceramic-coated tubes are easily

cleaned with hot water, this would reduce this cost and maintain full and unrestricted flue gas flow.

Because the test has not run for a longer period of time, operational efficiency and service life expectancy of the plain steel tubes in continued use can only be a matter of conjecture. Gas flow would become increasingly more restricted causing further efficiency drops while corrosion would progress to the complete penetration of tube walls. An additional questionable factor is the degree of heat transfer through the tube walls due to the ferrous sulfate deposit.

The major conclusion drawn from this test is that Vitralloy tubes, in spite of comparatively higher initial cost, can increase efficiency and decrease maintenance problems of air preheaters.

Air Pollution Control Association Meets in Chattanooga, Tenn.

THE 47th annual meeting of the Air Pollution Control Assn. held at Chattanooga, Tenn., May 3–6, 1954, drew better than 325 registrants to hear some 35 technical papers covering a range of air pollution control problems. Those papers of interest to the combustion and power generation fields are abstracted below. Many other papers dealt with process matters such as odor control and the different individual industrial plant solutions to local trouble spots.

Solid Fuels

The many phases of solid fuel burning were discussed. **Arthur J. Stock,** Stock Equipment Co., thoroughly covered one in a paper entitled, "Coal Segregation as a Cause of Smoke and Its Correction." The paper opened with a photographic illustration of a badly segregated fuel bed supplied by a chain grate stoker. This condition, the author maintained, could be duplicated by a faulty feed to a spreader stoker or underfeed stoker, especially of the multiple retort design.

The causes of segregation were traced from the coal car at the siding through the hopper to the furnace proper. Segregation caused early in this process sometimes cannot be subsequently corrected. Sometimes plant operation is the cause but the operators, themselves seldom have control over the segregation since it usually occurs within the coal handling equipment.

Mr. Stock advanced a number of remedies that varied with the point in the coal-handling movement where segregation developed. These remedies ranged from such simple procedures as multiple point loading up to the use of specially designed conical distributors to satisfactorily eliminate chute segregation.

But in addition to the difficulties of coal segregation there are those of air and moisture segregation. Air segregation results usually from poor design of air ducts or of the plenum chamber in stoker installations. But whereas many cases of poor fires have been charged to faulty air supply, coal or moisture segregation are by far the more likely trouble sources and the more serious.

Moisture segregation problems arise from irregular tempering of coal by steam in the stoker hopper. Mr. Stock recommended that where coal is to be tempered by steam it should be done in a downspout ahead of the distributor or the coal should be tempered by water as it is introduced into the bunker.

W. C Holton, Battelle Memorial Institute, in his paper, "Another Look at Reinjection of Flyash from Spreader Stokers," reviewed the major studies previously reported on flyash reinjection. From each he picked out the important advantages and disadvantages and weighed them against present day knowledge. Out of this approach Mr. Holton developed a number of conclusions and recommendations.

A careful study of the figures presented in the paper led the author to the belief that the design of boiler baffles and hoppers has a significant effect on flyash emission. The boiler pass hoppers, he believed, should be recognized as low draft loss collectors and so designed. Baffles should be so placed that changes in direction of gas flow would cause flyash to fall into the hoppers yet be so designed that erosion possibilities are minimized. In the past few years boiler manufacturers have become cognizant of these design advantages and are building them into their units.

Along with this progress in the boiler proper the stoker manufacturers have sought to reduce air infiltration and to lower excess air. New methods of reinjection have also been studied to lower flyash emission.

As a result of the definite improvement in the various responsible working elements of spreader stokers Mr. Holton felt the entire subject of flyash reinjection should be approached with an open mind. The data on reinjection are not sufficient to permit a blanket ruling for or against total reinjection. Each new installation should be judged on its own merits. If possible dust loadings on new units are to be predicted from published test results, the author cautioned air pollution control officials

to be certain that the units used for comparison are similar to the new in all major respects.

Instruments and Controls

A number of speakers devoted their papers to instrumentation or to controls on the various equipment contributing to air pollution. **C. H. Barnard,** Bailey Meter Co., explained in his talk, "Increased Efficiency and Decreased Smoke With Boiler Instruments and Controls," the very vital role that good meters play. As he pointed out the very small boilers do not burn enough fuel to warrant much of an expenditure for instruments and controls despite the rather high percentage savings they could effect. Where such aids are put on in the very small boiler they serve primarily for safety and reliability and to help in handling variable loads.

Large boiler installations work quite differently. There the advantages of increased efficiency represent such large fuel savings that extra instrumentation is justified. The improved operation carries with it the benefits of reduced smoke problems especially from partially completed combustion products.

Mr. Barnard described in detail a number of specific instruments designed to give better control of operating conditions within boiler furnaces. In summation the author expressed the conviction that the day of proper instruments and automatic control on all industrial boiler furnaces is no longer ahead of us. It is with us now.

H. C. Dohrmann, C. A. Gallaer, and **J. W. Schindeler** of Buell Engineering Co. gave a joint paper "Factors in the Design and Operation of Industrial Dust Collectors as Related to Air Pollution." In it they very early established the fact that almost any degree of dust collection can be obtained provided a company can or will meet the cost. For a boiler installation, as an example, the flue gas could be passed through several stages of mechanical collectors, then through 99 per cent elec-

tric precipitator, a bag filter and finally a wet scrubber. Stack appearance would be excellent but the installation and operation cost as well as space requirements would be unreasonable and prohibitive.

From a practical standpoint the major factor in dust collector selection often is price which includes not only the individual collector but the space it will take and the installation costs involved. Where such a condition exists the original purchase specifications must be made as accurate as possible and yet adequate to meet any existing or proposed dust ordinance. It is at this point where the authors feel most troubles with dust collectors start. The basic selection has been wrong and the equipment is doomed to failure from the start.

Next in order of dust collector difficulties, to the authors' way of thinking, was the question of dust design. The inlet to the dust collector is of extreme importance and a number of recommendations were made. Lastly the fundamentals of good operation were outlined and explained as a means of overcoming this phase of dust collector service failures.

G. V. Eiserman and **W. L. Prout,** of the Aerodyne Div. of Green Fuel Economizer Co., discussed "Factors Affecting Dust Collector Efficiency." Their paper was an extremely valuable one in that it sought to establish standards for rating dust collector performance. To make that uniformity possible the authors described the methods by which they evaluate the performance of their equipment.

They break down the variables influencing dust collector performance into four major divisions, namely, dust, fluid, operational and collector variables. By using the terminal settling velocity theory they simplify the effect of dust and fluid variables. And since these last named variables control both mechanical collector performance and terminal velocity the use of the terminal velocity theory gives good results in coordinating the vital factors. The authors supplied a number of equations to support this premise and then a fractional efficiency curve for their special collector.

W. L. Gabbert, American Air Filter Co., presented a paper, "Equipment for the Collection of Flyash, Dust, Soot, and Smoke from the Flue-Fed Incinerator." This particular paper covered the tests at the Dyckman Street project in New York City where each building consisting of 150 tenement units and fourteen stories in height was equipped with flue fed incinerators designed to handle 50 lb of refuse per day per dwelling unit or 7500 lb for each fourteen-story building. The feed averaged 50 per cent garbage and 50 per cent rubbish.

Development in the incinerator field has been encouraging and the use of an induced draft fan has aided this advance. But the annoying problem of positive pressures in the flue during fire cleaning periods has persisted. To get around this difficulty the author's company proposed installation of a string of collectors in series. Accordingly they put in a glass woven fabric collector, backed up by a highly efficient mechanical type filter and then a commercial, low-voltage electrostatic unit. Unfortunately temperature measurements at the base of the flue ranged from 300 to 1150 F with the peak occurring when the operator cleaned the incinerator fire bed. An exhauster on the system assured a constant induced draft over the grates and a flue base temperature of about 500 F but not at clean-out time.

Mr. Gabbert concluded that modern incinerators equipped with the above auxiliaries can do a highly satisfactory job of controlling air pollution except during clean-out periods.

Research and Studies

Considerable interest in methods of predicting future air pollution loads and then of reducing their effect was evident in a quantity of papers heavily research in character. The paper by **F. W. Thomas** of TVA, "Air Pollution Studies Program, TVA Steam Plants," was an excellent account of the approach large steam generating systems are taking in evaluating future power station sets. The TVA group have divided their air pollution studies into two distinct phases: (1) preoperational, (2) post operational. The chief concern has been the evaluation of SO_2 emissions from the plants so as to identify any needed control measures.

The preoperational phase was aimed at establishing baseline information for comparisons with data after operation of a steam plant had begun. Meteorological installations were put in at about the time construction was started which normally would give about two years of records before operation begun. This meteorological data included wind direction and velocity at or near the elevation of the top of the stacks, dry bulb temperature, wet bulb depression for relative humidity, vertical temperature differential between a point four feet above ground level and a point at approximate elevation of the stack top precipitation. In addition information on the agriculture and forestry in the area and the collection and chemical analysis of samples from selected species of trees were compiled. Such information has provided helpful guidance in positioning monitoring instruments and evaluating program effectiveness.

Once a plant has gone into operation

the next phase was set into motion. Meteorological observations were continued, routine monitoring by Thomas autometers begun, and special studies on dispersion initiated. The author gave specific examples to illustrate studies on effective stack height and diffusion. The information indicated that the effective stack height and critical wind speed can be estimated with sufficient accuracy for practical evaluation of air pollution control requirements.

In his summation Mr. Thomas mentioned that a special authorization to the Office of Chemical Engineering has enabled a research program to be started, aimed at developing a practical and economically feasible method of removing sulfur dioxide from flue gases and converting it into a useful salable product.

L. L. Falk, C. B. Cave, W. R. Chalker, J. A. Greene and **C. W. Thorngate,** E. I. du Pont de Nemours & Co., Inc., joined forces to present the paper "Development of a System for Predicting Dispersion from Stacks."

Starting with the well-known facts that wind speed and atmospheric turbulence markedly affect stack dispersion of effluents the authors set about determining the turbulent coefficients, then establishing the stack dispersion pattern from this data and relating it to a calculated ground level concentration that could be figured with a reasonable degree of accuracy.

The turbulence coefficients were identified with the aid of simple wind instruments. Then these coefficients were applied to the proper formulas to establish the stack dispersion factor. As a direct check on the accuracy of the measurements and the eventual calculations the authors employed a direct tracer technique by dispersing fluorescent particles from an elevated source.

Tests were made from an elevated source of about 100 ft and the downwind dosage pattern rather completely sampled. Variations of downwind concentrations with time were also measured. The authors summarized their results as follows:

(1) The dimensions of the ground-level dispersion pattern of stack effluents is related to simple measurements of wind speed and direction variations.

(2) Standard wind recorders provide information that can be used to express completely the dispersion pattern. A simple and readily available tool is thus available for determining dispersion from stacks.

(3) Working charts based on these wind measurements were developed for rapid calculation of the dimensions and magnitude of the average ground level concentrations. These calculated concentrations would in most instances be accurate to within a factor of two.

(4) The ratio of wind speed variability to mean wind speed was related to the vertical diffusion coefficient.

(5) The variability of wind direction was related to the horizontal diffusion coefficient.

(6) The ratio of peak one minute to average ground level concentration is related to the wind variability.

Still another paper, "The Role of Chimney Design in Dispersion of Waste Gases" by **R. H. Sherlock** and **E. J. Lesher,** Univ. of Michigan, analyzed the favorable and unfavorable factors influencing dispersion from stacks and chimneys. Stack height, gas velocity and gas temperature rate as favorable influences whereas aerodynamic forces, terrain and meteorological factors prove adverse influences. The most annoying problem is the one of downwash where the smoke plume drops to an undesired level within 2000 ft of the plant.

The authors pointed out that there is an economic limit to stack height. Industrial stacks commonly measure 250 to 300 ft high and one group of reinforced concrete stacks, the world's highest, will reach 680 ft above the ground when completed. But these extreme high units were adopted for a most unusual situation.

As a result the approach selected was to reduce the problem of downwash to its aerodynamic influences so control could be achieved by design without resorting to special research projects for each new plant. Only a short description of the wind tunnel testing procedures and equipment was given since this material is scheduled for later publication. The authors did, however, trace through a hypothetical case to explain the workings of a number of diagrams they have developed.

The knowledge gained from wind tunnel testing, the authors believed, would permit design steps that would practically eliminate the downwash of the stack plume toward the earth from aerodynamic forces.

Special Solutions

One of the more interesting accounts of an individual plant's handling of the air pollution problem appeared in the paper "Air Control and Research Program of the Kaiser Steel Corp." by **J. H. Smith** and **G. L. Rounds** of that company. This organization, with 59 stacks within its plant limits emitting all manner of steel-producing byproducts as well as power plant effluents, has been actively pushing air pollution control for the past eleven years. The plant is situated in the center of an agricultural area that has traditionally been extremely sensitive to possible SO_2 damage to vegetation and as a result very conscious of any air pollution.

The company has tackled the subject realistically and thoroughly. It has a staff of seventeen working full time on air pollution problems and, when needed, authorities from different specialized fields are retained to give solutions to difficulties beyond the regular employees' scope. This program is aimed at meeting all air pollution objections sensibly and to the point where pollutants create no adverse effect within the area. By reaching toward a desirable objective of no apparent damage to vegetation the Kaiser Corp. believes it can avoid the establishment of arbitrary standards that could prove unnecessary and costly.

Forum on Nuclear Reactor Development

An outstanding meeting covering several areas of nuclear reactor development was sponsored by the Atomic Industrial Forum, Inc., and held at the Sheraton Park Hotel in Washington, D. C., on May 24. The Forum is a nonprofit membership corporation with headquarters in New York City and traces its origin to a suggestion made in 1952 by Dr. T. Keith Glennan, president of Case Institute of Technology and at that time a member of the Atomic Energy Commission. Among its objectives are the encouragement of the utilization of atomic energy in accordance with the best traditions of democracy and free enterprise and the dissemination of information on atomic energy applications within limits of national security. In this the second meeting sponsored by the Forum and the first concerned with power reactors, participants discussed the five-year development program of the AEC, private reactor development, and public policy toward atomic energy.

Keynote speaker of the day was **Representative W. Sterling Cole,** chairman of the Joint Congressional Committee on Atomic Energy. Representative Cole, who was introduced by **Rear Admiral Lewis L. Strauss,** chairman of the U. S. Atomic Energy Commission, stated that the Joint Committee is attempting to revise the Atomic Energy Act of 1946 so as to make public policy conform to present realities of the national and international scene. He strongly empha-

sized that the present revision is *not* an atomic power bill, which will have to come from a future Congress. The current proposal is intended as a modernization of the McMahon Act and deals with a score of problem areas, of which atomic power is only one.

Observing that atomic power as a practical economic proposition is not yet existent, Chairman Cole stated that the problem of the Joint Committee is one of devising ways and means of hastening the day when there will be a need to make power policy. This can only come by encouraging the speediest possible attack on unsolved technical problems to make competitive atomic power a reality. He had the following to say about participation by private enterprise in the solution of these problems:

"If free enterprise is some day to secure a fair return on money invested in atomic power plants, free enterprise must also be prepared to assume its fair share of the load in the pioneering years immediately ahead. During these years, for the most part, atomic power will not be cheap enough to furnish a reasonable return to private investors. If we are to speak in terms of equity for our taxpayers, it seems to me that the real 'atomic giveaway' would result from private industry abstaining from participation in the development of atomic power until such time as entry into this field promised generous and assured rewards. I therefore say that the participation of free enterprise during the pioneering days of atomic power should be regarded as a responsibility—not a privilege."

Government Program for Reactor Development

Opening a panel discussion on the five-year development program of the AEC, **Dr. Lawrence Hafstead,** who is director of this program, emphasized that the long term goal is to make nuclear power cost less than that from conventional sources. He described the reactors being constructed under the present program as representative of the second generation of reactors. Reactors to date have involved high capital costs, but there are no laws of nature which will prevent reduction in these costs, especially as it becomes possible to get away from custom building.

Dr. Chauncey Starr, director of atomic energy research for North American Aviation, Inc., confined his remarks to the liquid-sodium-cooled reactor. This type permits very high operating temperatures without pressurization and offers the possibility of thermal efficiencies on the order of conventional steam cycles. Future plans

for this type of reactor include the hope of increasing initial temperature from 900 to 1200 F, with corresponding gain in thermal efficiency. The present development program with sodium-cooled reactors has among its objectives reduction of costs of fuel, moderator, coolant, coolant system, structure and shield. In years to come it is hoped to achieve power costs on the order of 4-5 mills per kwhr, or about half of the current estimates.

The third speaker on the panel was **Charles H. Weaver,** manager of the Atomic Power Division of Westinghouse, who discussed basic design considerations for the central station nuclear plant to be built for the Duquesne Light Co. Mr. Weaver's remarks appear in more complete form elsewhere in this issue, pp. 38–42.

Dr. Alvin Weinberg, research director of Oak Ridge National Laboratory, proved to be a strong advocate of homogeneous reactors which have inherent simplicity because of the combination of a chemical processing plant with a power plant. This simplicity is achieved at the expense of more complex materials handling problems resulting from the circulation of extraordinarily radioactive materials at uncomfortably high pressures and the severely corrosive nature of the circulating fluid. Dr. Weinberg developed an argument for analyzing total costs of nuclear power in a way such that thermal efficiency would not be the most important criterion, as it is in many steam plant studies. He urged that more attention be given to costs of nuclear fuel burnup, reprocessing and controls in the belief that the minimum might be obtained at other than the most efficient thermal cycle.

The final speaker on this panel was **Dr. Walter H. Zinn,** director of Argonne National Laboratory, who provided some information on the Boiling Experimental Reactor (BER) and an intermediate-size Experimental Breeder Reactor (EBR-II). Among the advantages of BER are the elimination of the type of steam generator normally required for water reactors, a downsizing of pumps by a factor of ten from those used in a circulating-water reactor, and a reduction of the amount of shielding required in the piping system of the reactor. On the other hand BER has the disadvantage that slightly radioactive steam will be passed through the turbine and may cause serious maintenance problems.

EBR-II is intended to be a test of the ability to design a reactor satisfactory for large power plants. Its steam system is to correspond to modern central station practice and is expected to have a thermal efficiency on

the order of 35 per cent. The gross thermal power in core and blanket will be approximately 62,500 kw, with a net electrical output at 15,000 kw. The design of EBR-II is based on the premise that its fissionable material will be plutonium. Initial feeding can be done with U^{235} but part of the engineering test is to be a demonstration that fuel cycling is both practical and economical.

Private Reactor Development

Participants in the panel on private reactor development were representatives of three industrial teams and two independent companies. **C. R. Barthelemy,** project engineer of the group which includes Foster Wheeler Corp., Pioneer Service and Engineering Co. and Diamond Alkali Co., stated that the objectives of the group with which he is associated were similar to those of the four original groups except that the dual-purpose aspect of reactor development did not play a prominent rôle in the studies. As was the case with other study groups, the importance of finding means to reduce capital costs was stressed. Mr. Barthelemy pointed out that the critical amount of fuel required to keep a chain reaction going in a reactor may involve as much as 10 to 25 per cent of the initial investment. His group studied the circulating-fuel thermal breeder type of reactor and found that it had certain advantages in terms of cycle stability and relative ease of fuel processing. Some investigations were made with the intent of adapting fluidized-bed techniques to reactor design but results were not conclusive.

Reporting for the Dow Chemical–Detroit Edison group of companies was its project manager, **Alton P. Donnell.** This group, which has a 1954 budget in excess of $2,000,000, is directing its efforts toward development of a satisfactory design for a fast-breeder reactor. Work is being undertaken on the possibilities of remote fabrication of fuel elements in combination with some form of metallurgical processing. Mr. Donnell expressed the belief that markets will develop for fissionable materials produced in reactors. Reactors now under design may have a very rapid rate of obsolescence, but the end result should be a considerable reduction in capital costs.

The next speaker was **Titus G. LeClair,** chairman of the operating committee of the Nuclear Power Group which includes American Gas & Electric, Bechtel Corp., Commonwealth Edison and Union Electric. This group is concentrating on design of a pressurized water reactor employing heavy water as both a moderator and a coolant. Studies for a 150,000-

kw unit indicate power costs of 12 mills per kwhr, while for a unit of 300,000 kw, considering anticipated reductions in the cost of the fabricated fuel and heavy water, indications are that power cost may be as low as 7 mills per kwhr. The group is also considering designs for a boiling reactor plant and is making preliminary studies of a homogeneous reactor designed solely for power production.

Francis K. McCune, general manager of the Atomic Products Division of the General Electric Co., made known his company's position in the following points:

1. The electric utility industry will be owing and operating a number of atomic power plants within the next ten years.
2. Some of these will be full scale and will generate electricity at competitive costs, possibly within five, and certainly within ten years.
3. It is believed that this will be accomplished without Government subsidy for plant construction or operation and that fuel supplied by the Government will be priced in accordance with cost of production.
4. The two nuclear reactors offering the greatest promise for rapid development and competitive use are the light-water-moderated and cooled boiling reactor and the graphite-moderated water-cooled reactor.

Mr. McCune declared that one of the most critical problems is the development of a satisfactory fuel element. Many of the groups of experts now studying this problem are confident that an adequate solution will be found. He stated that one of his company's reasons for being enthusiastic about a light water boiling reactor is its many similarities to conventional steam plants, which may contribute to its adoption by the electric utility industry. The boiling water reactor has demonstrated safeguard advantages so that operating companies should be able to choose plant sites as available within their systems

Concluding speaker on the panel was **Dr. Philip Powers,** director of the atomic project sponsored by the Monsanto Chemical Co. His organization visualizes the reactor as having potential sources of income from (1) heat to produce electricity, (2) nuclear fuel, (3) the manufacture of chemical products. Noting that it is still not clear whether the Government will buy fissionable material from industry and that there is as yet no change in the law regarding private ownership, Dr. Powers implied that lack of knowledge of future policy was discouraging to some groups which might otherwise make substantial investments in the development of reactor technology.

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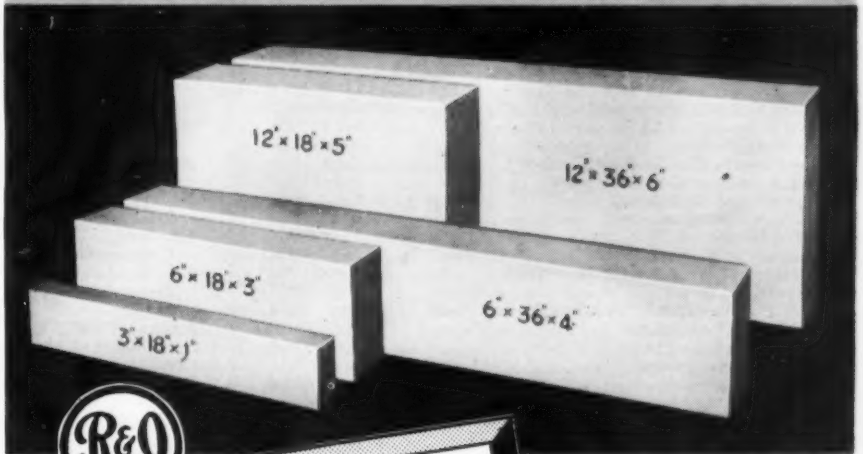

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COMBUSTION, Volume Twenty-Five, July 1953 Through June 1954

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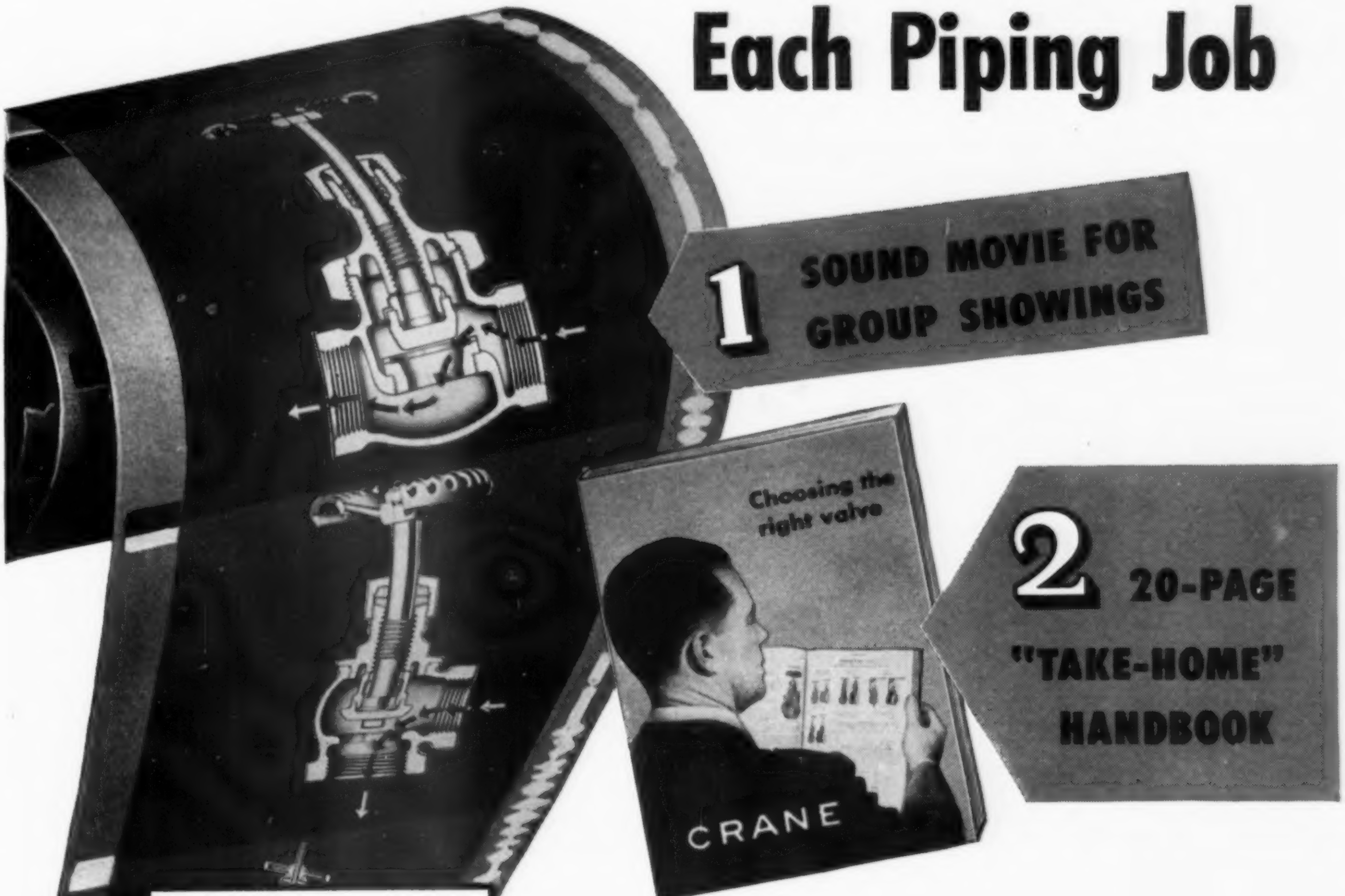
2 New Services from Crane

How to Choose the Right Valve for Each Piping Job



HOW TO GET THESE FREE HELPS

Easiest way: phone your local Crane Representative—let him schedule a film showing for your group and supply the "take-home" handbooks. If more convenient, just drop a line to the address below.

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Following a review of basic valve types—gate, globe, angle, and check—variations in design of functional parts, and the effects on serviceability are discussed. All vital elements—disc and seating—disc-stem connection, bonnet joint, stem operation, etc., are covered. The motion picture stimulates high interest by developing a hypothetical case involving strong differences of opinion on valve selection. The manual—intended for distribution at film showings or for independent use—provides a lasting reference.

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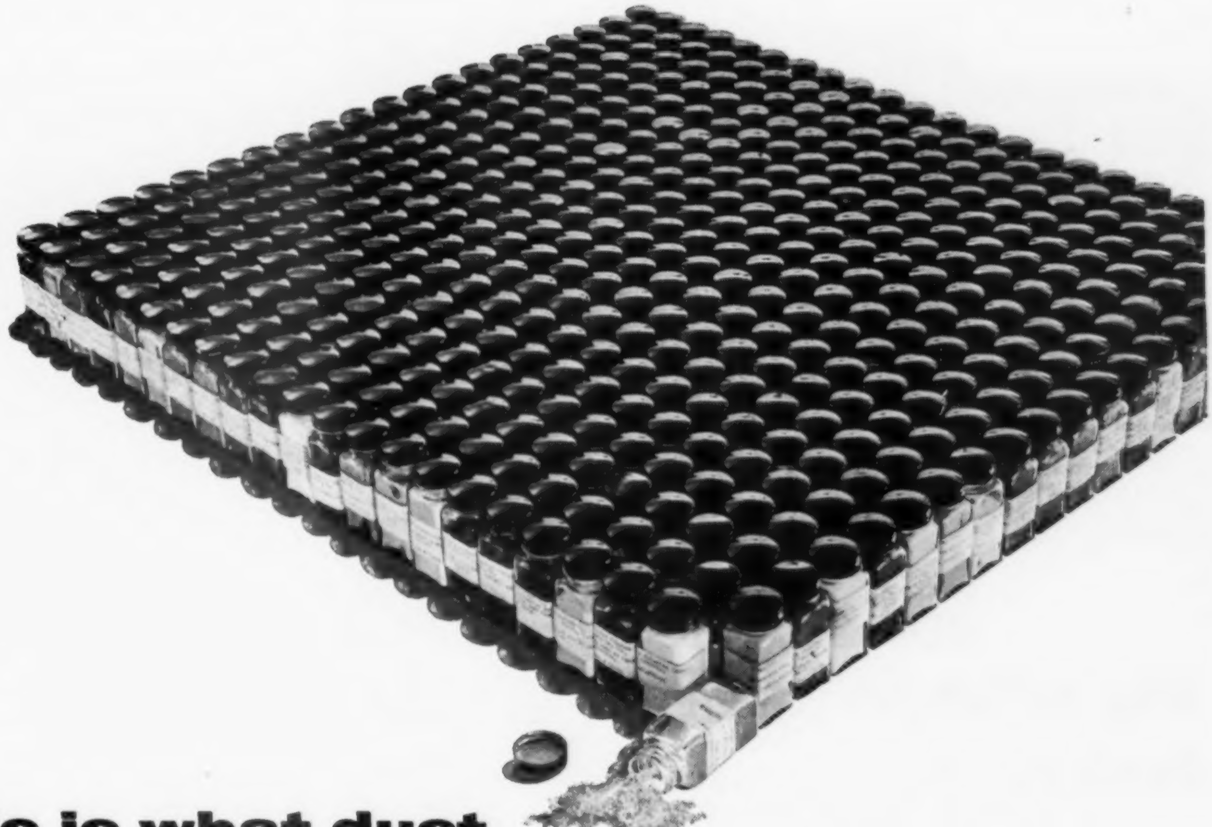

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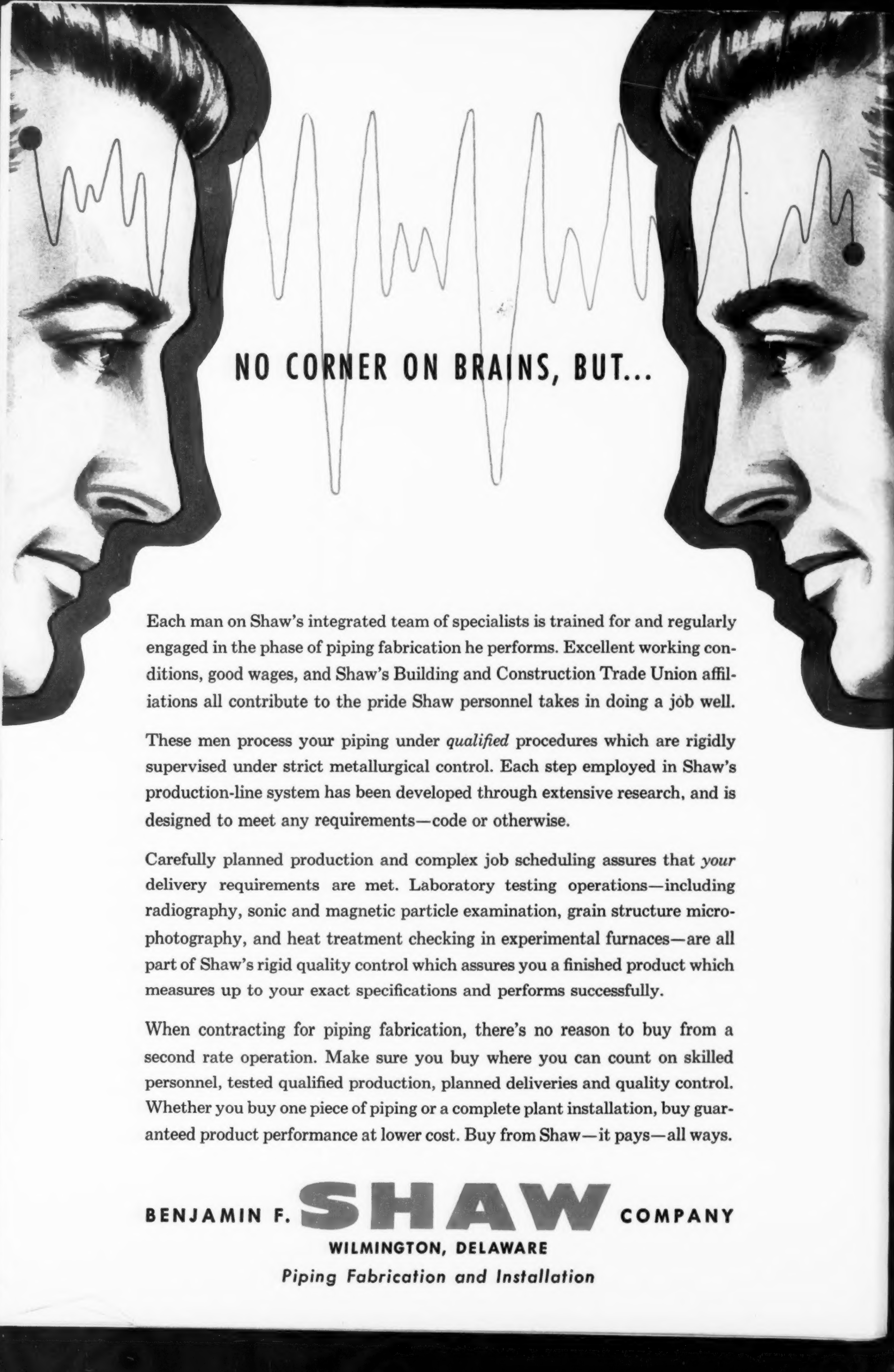
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